ELECTRICAL CONSTRUCTION AND MAINTENANCE

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A practical technical and management journal for electrical contractors, industrial electricians, inspectors, engineers and motor shops, covering engineering installations, repairing, maintenance and management, in the field of electrical construction and maintenance.

July • 1948

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JULY . . . . at a Glance

Methods

The space we usually devote to feature stories and more is occupied in this issued by "Electrical Construction Methods", a special editorial feature section. In it we have brought together a substantial portion of industry techniques and know-how in one compact work. It is one of the largest and most complex projects ever prepared by our editorial staff. It is intended to be a directly useful tool in print for the electrical contractor and all concerned with electrical construction work.

Taft-Hartley In Construction

For the first time where the issue was contested, the NLRB recently voted to assert jurisdiction over the construction industry under the Taft-Hartley act. General Council Denham had previously assumed jurisdiction in some cases particularly where secondary boycotts were involved. While it has been reasonably clear since the law passed the Congress that construction work would eventually be covered in the procedure, the construction industry offers one of the most complex possible patterns for its application. In the preliminary phases of bringing industry practice into conformity with the law, it is to be hoped that most of the procedure can be worked out through negotiation and cooperation with a minimum of recourse to the courts.

Check Figures

In last May's issue an analysis of residential wiring costs developed the effects of economic and adequacy changes on the price of house wiring. The figures used were developed as accurately as possible, however, no claim was made that they would apply generally over the country. They were checked anyway by research to spot important variations. The results were actually in closer agreement than we would have been willing to predict. Specific variations of as much as 10 percent were reported from the published figures. The majority, 51 percent reported their prices "about the same" as those published, 30 percent said their prices were "higher" and 19 percent said they were "lower". Thus, the published material was pretty close to the average.

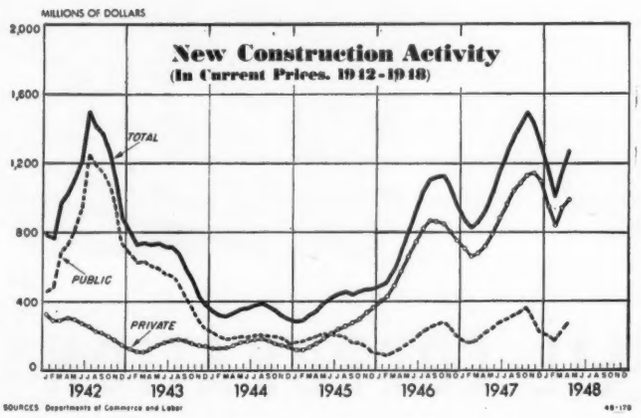
Looking Ahead

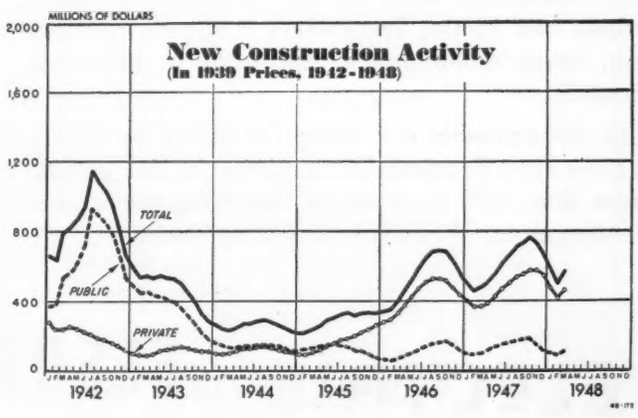
Illumination recommended and used in industry over the past 30 years has doubled every ten years. The same growth is apparent in school classroom lighting. Most significant, however, in the past ten years is the improvement in quality of lighting as well as increased intensities.

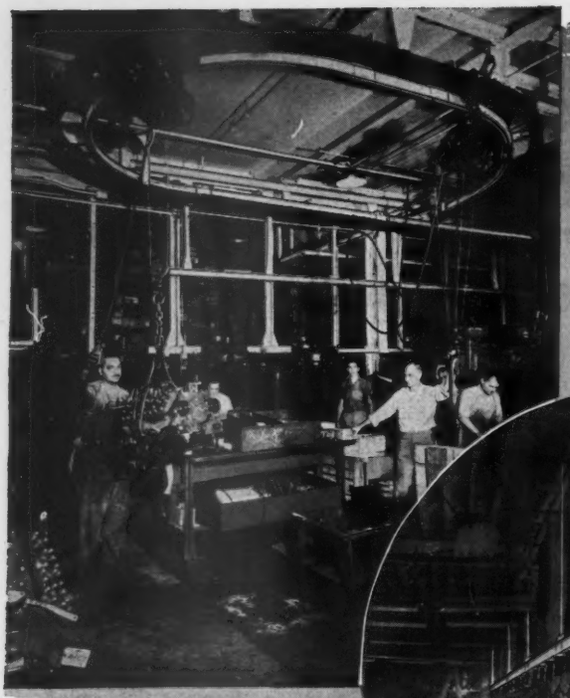
To produce such orderly development over a long period of time would do credit to a laboratory. But this progress is taking place in ordinary industry and commerce. It involves scientists, engineers, salesmen, electricians, utilities, contractors, manufacturers, wholesalers and many others in enthusiastic teamwork in a project which historians will certainly record as importantly affecting our way of life.

It is entirely fitting to hail some of our modern lighting jobs as great achievements in which we may all take pride. It is well to keep in mind, however, that there is little evidence in lighting technology to indicate we are much nearer a practical optimum. As the frontiers move forward the horizon recedes.

To project the historical progress curve cautiously into the future is a fair appraisal that ought to give us guideposts in which we may have substantial confidence. To confuse things, however, future developments are likely to follow other factors than footcandle growth. In any case, the realities of future lighting progress are more likely to tax our imaginations than our abilities in critical forecasting.



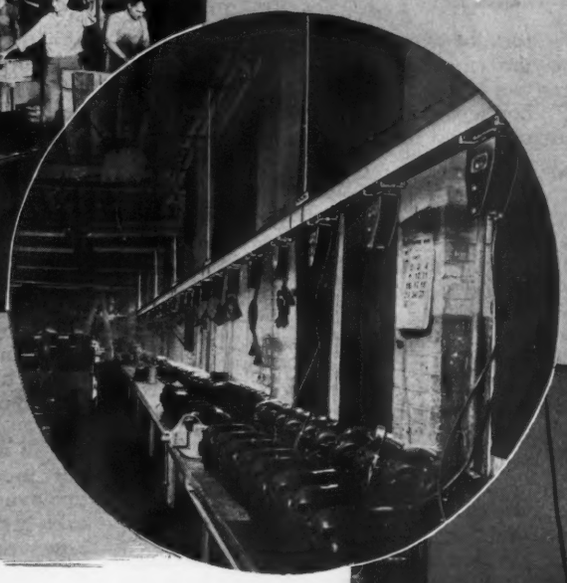




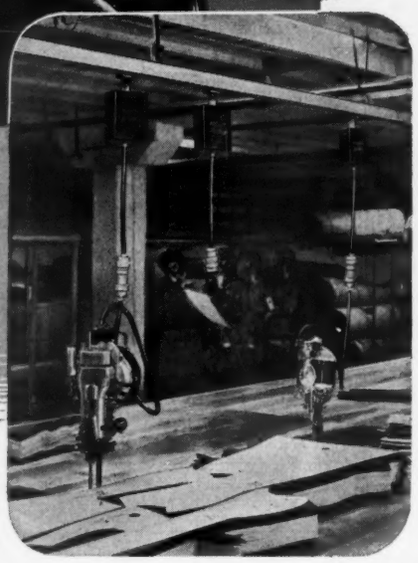
Overhead

On Test

On the Production Line



On the Bench



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HOW MUCH FOR WIRING?

CONTROVERSY over the cost of house wiring pops up periodically. It is with us today. And the arguments are much the same as those of the thirties and even back to the twenties. The amounts are different and new voices are heard but the reasoning is forever the same.

WIRING COSTS must come down to 1) reduce the high price of housing, 2) lower the installed price of high wattage appliances and 3) promote greater adequacy through lower unit costs. All of these objectives are laudable and sound well in public statements. But what we really mean is that we don't know how to sell wiring and we hope that if the price is low enough we won't have to.

LET'S GET our perspectives straight. Lower priced housing is a great sociological objective. In a burst of idealism we'll do the utmost at great sacrifice. We'll eliminate the wiring entirely. The net result will be a tremendous reduction of maybe 5 percent of building cost or roughly the inflationary increment of the past *four months*. Lets face it. The most radical reduction in wiring costs wouldn't cause a detectable ripple in the economics of housing.

HOW ABOUT appliance installation? Here we are reaping the penalty of decades of shortsighted wiring installation design. With perfectly clear charts of continued utilization growth under our elbow, we wired for connected load. We still do. So major appliance installation calls for major rewiring at considerable expense. Should the price of such installation be battered down to paper thin margins? Real cost reduction is in quite the opposite direction. As sound profitable business it can attract the brains, engineering and initiative that will bring economical materials, methods and management to bear.

LOWER UNIT wiring costs are a *result* of aggressive merchandising. They are not a cause. In wiring there is no clear history that lower unit cost has sold greater adequacy. Yet greater adequacy always brings lower unit cost. Wiring requirements vary widely in different cities. We have found no significant correlation between the type of wiring system and prevailing adequacy standards. Yet we find great improvements in adequacy standards where adequate wiring has been merchandised and promoted.

CONTROVERSY over the cost of wiring is of no great importance in itself. Wiring costs are largely determined by plain economic and business consideration in the communities where the work is done and the factories where materials are made. But cost reduction can become such a compelling objective in men's minds that it diverts and divides energies away from the obvious needs of more and better electrical utilization. A cut of fifty cents an outlet is a tangible and demonstrable achievement that saves facing the appalling job of selling even moderate present day adequacy in new homes.

HOW MUCH SHOULD WIRING COST? Maybe a third of today's prices, maybe three times as much. The only way we'll ever find out is from hard hitting, industry-wide sales effort beyond anything we have known before. Until we realize the importance of wiring, learn to sell it and to convince the public of its essential place in modern living it will cost too much at any price.

Wm. F. Stuart

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Electrical Construction METHODS

Modern practices in electrical construction design and installation are compiled in this comprehensive review—a special editorial feature section complete in this issue.

How are wiring systems planned? How are they installed? The answer to these two simple questions encompass a substantial part of the great, growing technology and practical "know how" of the electrical construction industry. In the following pages we have brought together a comprehensive review of industry methods. We have developed material from many helpful sources. We have drawn upon our own years of experience and direct participation in the industry. We have leaned heavily upon literally thousands of personal contacts with contractors and jobs to make this editorial project thoroughly practical and up-to-date.

This work is intended for practical men who are actively engaged in electrical construction work and who bear the responsibility for planning and execution.

It deals with the planning, design and carrying out of electrical construction projects of the types most frequently encountered in commercial and industrial building. The methods shown and described are practical in experience. They are not thereby preferred or exclusive of other methods. Experienced job management, engineering and supervision must in practice decide, adapt, choose and select the methods which will be best for the particular job. This work will form a useful and handy guide.

The arrangement of the material is substantially in the order in which methods are applied to the job—management, engineering, layout, installation, and wiring in special areas. Several useful tables pertaining to all parts of the work are included for reference.

Necessarily the material is abridged. Many obvious and routine practices known and used everywhere have been intentionally omitted to permit detailing less well known methods. Comments and inquiries from our readers about any methods discussed are cordially invited.

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METHODS... MANAGEMENT

Contract Closing

JOB operations start with the contract. In electrical work contract closing may follow various patterns from elaborate contract documents to an informal exchange of letters. Good business housekeeping, however, includes a set procedure that can be readily reviewed and backed up at any stage of the work.

Several points should be already covered during the contract closing, however informal.

1) An order in writing
2) A clear definition of the scope of the work
3) The exact price or contract
4) The terms of payment

When formal contract documents are used, these points are usually covered carefully. Many projects, however, are closed by acceptance on a purchase order of a bid or proposal. If the proposal is carefully prepared to cover the above points it is usually adequate.

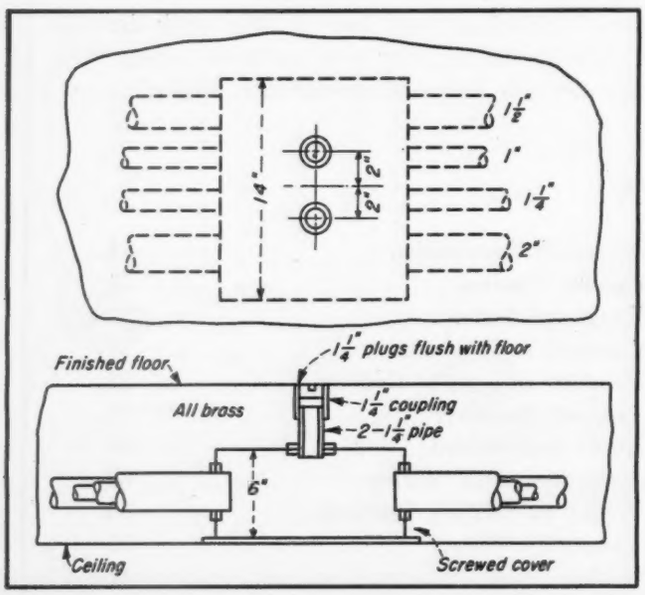
If the plans and specifications are revised during bidding or negotiation it is important to indicate exactly what revisions are covered in the proposal. When plans and specifications are received they should be promptly checked against the estimate and proposal and a copy filed with the contract documents.

A clear definition of the scope of the work is, in practice, an ideal rarely attained but it can be approached. Good plans and specifications help. When no formal specifications are available the proposal should include an accurate and comprehensive description of the work intended.

Preliminary Planning

At an early date after contract letting it is customary for the architect and owner to call in the contractors for a preliminary time schedule. The electrical work is rarely a deciding factor in job schedules, but it is important that the contractor be thoroughly familiar with the plans at this time and probable delays in materials delivery. Principle points to check in the preliminary schedule are 1) long standby periods requiring one or more men on the job continually but with little productive electrical work possible. 2) large peaks in labor requirements. 3) extended completion schedule which may tie up final payment over minor finishing items.

From the preliminary time schedule the next step is a job conference with the estimator, engineer, superintendent, buyer and the foreman who will be assigned to the job.



DETAIL DRAWINGS give precise dimension and accurate assembly information.

Job Management

Top organizations for job management may follow a variety of methods. Most, however, are minor variations of one of the following plans.

1. Staff management which involves foremen reporting to a general superintendent in charge of all labor operations, an engineer in charge of methods and procedures and a buyer in charge of materials and delivery all reporting to an executive head or general manager. The staff with necessary consultants handles all jobs taken by the firm.

2. Estimator-engineer-manager operation places full responsibility on one man who follows the job from the estimate to final completion. He calls upon assistants and staff but has final authority on all decisions and actively handles the work.

Which of these two organization methods are followed and variations therefrom are determined by executive policy and practice. Both are efficient and successful. If the front office is operations minded and in close touch with business details the staff method is preferred. If the boss is inclined to delegate operating authority and responsibility or primarily concerned with sales and finances the estimator-engineer-manager method is useful and practical.

In either case lines of authority and responsibility should be crystal clear. Team work is essential and enough authority ought to flow down stream to keep the locknuts and bushings out of the front office. Waiting for minor decisions costs just as much per hour as productive labor.

Cash Flow

Money costs money, whether its your own or borrowed from the bank. It is advisable to set up a cash flow schedule on sizable jobs to detect and avoid unnecessary peaks and emergency borrowing.

The key to cash flow is the program schedule. Labor requirements can be estimated from it and monthly payroll approximated. Materials delivery schedules will give the approximate amounts needed to discount bills each month. Other job costs can be prorated or weighted along the time axis together with out-of-pocket overhead. The totals will give the monthly outlay.

On the same time axis enter the expected monthly payments allowing for a realistic time lag and the retained percentage. Deducting the expected payment from the estimated cash outlay for each month will show the ready cash required.

Many successful electrical contractors prepare complete working drawings regardless of how thorough the original electrical drawings may be. The practice ought to be uni-

JOB OFFICE handles management and field engineering, Fischbach & Moore at Davenport Aluminum Co. plant site.

versal. Conduit sizes, circuit runs, dimensions and many other details of the installation have to be worked out by someone sometime during the work. It is far more efficient and much cheaper to develop such details in the quiet of a comfortable drafting room under good lighting with all the drawings, specifications, catalogs, data tables and staff consultants immediately at hand than piecemeal under the strains and distractions of job operations.

Working drawings are rarely elaborate. Good pencil tracings are most widely used. Only the bare essentials of structural features are drawn in. Electrical details are shown thoroughly including all conduit sizes, runs, hangers, inserts and critical dimension data. Good working drawings make it possible for the job to proceed with a minimum of critical judgments or decisions by the mechanic or foreman. Further, they organize the job the way it was estimated which helps in ordering and scheduling materials.

Detail drawings are required for many parts of the job where trade conflicts occur, dimensions are tight or special equipment involved. Some can be prepared in advance, however, many must be developed from measurements taken on the job during actual construction.

Plans

With the electrical drawings and specifications the architect usually furnishes a set of construction drawings. They are the formal source of important dimensions and should be compared closely with the electrical plans. The following items should always be checked.

1. Service entrance or main switchboard
2. Main feeder runs
3. Risers and riser shafts
4. Major equipment locations.

Discrepancies between electrical and structural drawing affecting installation should be checked with the architect early. It is usually impossible to detect all trade conflicts ahead of time but straightening out as many as possible before construction starts can save much costly job time.

Electrical installations rarely conform to the letter of a set of plans and specifications, although the scope and intent of the original plans are followed. Too many variables enter the picture. Last minute changes, job conditions, structural conditions, interference with other trades and other unanticipated factors frequently dictate what installation methods are to be used. Design engineers appreciate this possibility and permit the electrical contractor sufficient latitude to use his own judgment on the construction project.

Once the plans and specifications are on the job site, the field engineer, construction superintendent, or job superintendent depending upon organization makeup, is the key man on the project. He is responsible for adapting the plans and specifications to the specific job. He must decide where raceways are to be installed; how they are to be mounted; how to overcome structural obstacles; where and what type of pull boxes are needed; how to install the cable and make connections. This in addition to his job of organizing his men into efficient working crews. Being close to the job and in constant touch with problems that arise daily, he is in a position to make recommendations and decisions that frequently result in a better electrical installation with economic advantages to both the owner and contractor.

The impact of such on-the-job decisions cannot be overemphasized. All parties concerned with an electrical installation lean heavily on this key man's knowledge and experience in the construction field, his up-to-the-minute knowledge of materials, his foresight, and his ability to efficiently work and cooperate with other building trades on the project.

Field Engineering

A construction project is engineered until the last brick is laid, until the last fixture is installed. Such on-the-spot attention is provided by a field engineering force. On large projects, contractors, architects, consulting engineers and owners maintain resident engineers on the job site to make decisions, authorize changes, resolve differences that might

GOOD MATERIALS control is essential to efficient job management and orderly schedules.

arise. In the case of the electrical contractor, this might be a man from the home office or the job superintendent.

Field engineering functions basically follow the natural sequence of construction progress. Fundamentally, they fall into three distinct classifications:

1. *Planning*—As applied to the construction field, planning is essentially a matter of material and labor control—having enough material and men on the job to keep pace with or keep ahead of other trades. This is of utmost importance on concrete work where circuits are to be concealed and sleeves, inserts, feeder and branch conduits, outlets and cabinets must be installed on the forms or building skeleton before the concrete is poured or brickwork started. This phase requires closest cooperation between the various trades to catch last minute changes. It's a lot easier and more economical to change a conduit before the pour than to chip concrete later.

Planning is equally important on exposed raceway systems—particularly if other pipe trades are involved. Unless previous arrangements have been made, it's generally the case that the first trade there has clear sailing and others must get around them as best they can. Right-of-way where several pipe systems must, of necessity, be in close proximity of each other, it is a matter that can be resolved only on the job site where structural conditions are out in the open.

2. *Layout*—A certain amount of overlapping occurs between planning and layout on concealed systems where outlets and conduits must be in place before the pour; or in suspended ceilings where work must be done before the ceiling framework is hung. Here, both go hand-in-hand.

Normally, layout involves spotting of outlets, panels, branch circuit and feeder conduit runs to provide the shortest distance between terminals, while still conforming to structural limitations and building lines; also the design of pull boxes, cable troughs, terminal boxes and other items that will facilitate cable installation and equipment connection. It differs from the general system layout of the design engineer in that it deals with details pertinent to installation practice. Here detailed drawings, patch-sections of general plans and field sketches play an important role. Specific attention should be directed to multiple conduit runs in trusses, riser shafts, columns, etc., to prevent confusion and facilitate feeder or circuit identification for cable installation.

Layout is vitally important where bus duct is to be installed. Manufacturers require precise dimensions to fabricate duct runs to conform to actual installation requirements. Those dimensions can be had only on the job site. A small error can throw an entire duct run out of kilter, especially where a structural obstacle must be by-passed.

Accurate field dimensions are also important where large groups of conduits enter a switchboard, panelboard, pullbox, cable strain box or change direction.

3. *Installation*—The biggest and final phase of any electrical project (with the exception of testing) is the installation of the equipment, conduits, cables, panels, outlets, fixtures, and other accessories that make a complete job. Here the contractor has a choice of several methods. The technique he finally employs will depend upon conditions at the project. It is not uncommon for a contractor to secure authorization to substitute equipment of quality equal to that specified, because the substitute offers installation economies and advantages.

Materials Control

Some good inventory control system is essential to effective job management. The most flexible and one of the most widely used is the "job envelope" method. Duplicate invoices and duplicates of requisitions from stock are filed in a monthly envelope under the job number. For checking or cost analysis the "envelope" may be subdivided as much as necessary.

On-the-job stock is inventoried once a month as a rule. On very large jobs involving extensive stocks more or less elaborate stock controls are used, however the "envelope" principle remains the same. First of month job stock *plus* charges *less* credits *less* first of following month job stock gives materials in place during the month.

Critical accuracy in stock taking is rarely necessary since minor errors wash out as the job moves along. Small bulk items are often covered by a reasonable miscellaneous item.

A well organized periodic materials control system on the job is a valuable source of progress and job management data.

Materials in place can be set up on piecing sheets and unit labor costs applied. The results compared with payroll gives a quick and accurate check on the original estimate, job efficiency and progress percentage. By isolating portions of the work in the job envelope accurate and useful cost data can be accumulated for bidding and planning.

Job Time Schedule

One of the most useful devices in job management is a well prepared time schedule. It is usually set up very early, the earlier the better, in consultation with the architect and general contractor. Schedules vary from simple letter sized sheets to elaborate production control boards.

Basically job time schedules consist of a chart ruled horizontally. Horizontal divisions are scaled according to a convenient unit of time, usually working days.

Important elements of the work such as major equipment, roughing, cable work, finishing, etc. are listed vertically in whatever breakup is most convenient for the job. The amount of detail shown will vary with the type of job and the information and control desired. The following is a typical list for a moderate sized school building.

Temporary work
Basement Roughing
First floor Roughing
Second floor Roughing
Service entrance
Feeder conduits
Panel cabinets
Panels and covers
Signal junction boxer
Exposed basement conduit
Feeder wires
Branch circuit wires
Wiring devices
Motors and control
Fixtures
Signals and clocks
Inspection and testing

Through any convenient set of symbols, job functions are projected for each part of the work along the time axis. These include: 1) materials orders placed, 2) delivery dates, 3) details drawings prepared, 4) installation, and 5) completion.

A common and very useful practice is to parallel the installation symbols with an approximation of the labor force required. If carefully projected many unnecessary peaks and valleys in labor requirements can be predicted and the schedule altered to smooth up the curve.

On large jobs, time schedules are ordinarily set up on a large master tracing. Prints are distributed to the job office, buying office, estimator, superintendent and executive office. Daily progress is entered in colored pencil. The master tracing is corrected once a month or weekly as control requirements dictate.

Buying

Materials and purchase services account for more than half of average new construction electrical work. The "standard" cost ratio of 60 percent materials and 40 percent labor is frequently used in analysis and appraised. Obviously no such ratio can be continually applied to individual jobs but it gives a fair indication of the importance of well organized and highly efficient materials procurement.

Recent years have brought unusual conditions into the work of supplying the job. However, the basic considerations are much the same in "normal" or "abnormal" times. Selected materials must be purchased and placed in the hands of the workmen at an advantageous price and according to an efficient schedule. Further, there is a relationship between materials selection and labor cost. During the war and on many projects since other than normal business considerations were compelling enough to upset much conventional procurement practice. However, with the possible exception of materials in extremely short supply, ordinary distribution channels are efficient and economical. Much has been written and spoken about the high cost of distribution of building materials, yet no alternative channels offer any substantial improvement.

On major equipment the specification usually offers the contractor a choice of two or three manufacturers, often others with the permission of the architects or owner.

If quotations have been sought for bidding, negotiations can proceed at once. Good ethics dictate that the order should go to the firm whose price was used in setting up the bid. This is particularly important on special equipment to be custom built for the job, special fixtures, for example, or switchboards and panels.

When identical quotations have been given to all bidders, the successful contractor may not feel an ethical obligation to place the order with the firm offering the lowest price even though the price was used in making up the bid. In this case he may offer a favored firm the opportunity to meet the low price or he may buy at a higher price if features of the equipment offer the possibility of a lower installed cost or more certain delivery.

Shopping is still practiced, though much less than in more highly competitive times. Three or four of the firms offering the lowest prices are set against each other in an attempt to drive the price down. In the long run the practice is of questionable value in reducing prices and is widely condemned. When suppliers think their prices are likely to be "shopped" they simply withhold their "best" price for final negotiations.

Substitution of material of a lower quality or price for a well known established line without the permission of the architect or owner is not so prevalent in electrical work. The standardization which prevails in the electrical manufacturing industry for materials of equivalent function leaves little room for large price differences. Most contractors however, have favored suppliers and manufacturers whose products they prefer and with whom they will work most effectively to obtain approval for substituting the preferred lines.

Many contracts based upon bid prices even today contain an escalator clause. In effect the contractor offers to do the work at a fixed price with the condition that cost increments between the time of bidding and the completion of the contract will be absorbed by the purchases.

The practice is rapidly disappearing. Born of economic inflation, it is an effort to protect against a type of risk over which the contractor has no control. No one likes the escalator clause. It will be abandoned as soon as stable commitments can be obtained upstream on both price and delivery.

Materials Schedule

A proper flow of materials to the job is one of the contractors most important job management responsibilities. When lead time is long and supplier short it becomes even more critical. Since materials flow has a direct bearing on schedules and labor efficiency, material supply is much more than shrewd buying. In electrical work the supply function is not completed until the materials are installed in place.

Under present market conditions orders are usually placed immediately after the contract is closed with a tentative shipping date. Later as job schedules are prepared the shipping date is narrowed down. Some lead over immediate job requirements is essential, however, too long a lead may involve expensive warehousing off the site, special protection and precautions on the site or multiple handling.

Close cooperation between suppliers and the contractor is usually a matter of long experience and efficient management. On occasion, some owners prefer to bypass this established teamwork by negotiating directly with suppliers or manufacturers for equipment and major material items. Such arrangements, though they may seem to eliminate the contractors necessary margin are uneconomic and very risky to the contractor. He often finds it necessary to work with the owner or procurement without appropriate compensation to protect other job costs. Many contractors as a matter of considered policy refuse work where they cannot have complete control of materials supply.

Delayed deliveries are invariably expensive. Jobs are held up while fixed costs go on. More power has to be shifted and schedules reworked. Expensive expediting may be required.

Bad materials scheduling and handling can often incur costs substantially in excess of competitive prices differences. Effective scheduling and control of materials supply is the essense of prudent buying.

METHODS... SYSTEM ANALYSIS

TO a great extent, satisfactory electrical design is dependent upon analysis and selection of methods: methods for generation, transformation, regulation, distribution, protection and control. Never before has this been more important, for faster-paced production schedules and tighter economic limitations make it imperative that plant efficiencies be maintained at their highest levels. As industrial and commercial establishments become more and more dependent upon electrical operation, production efficiencies and economies become increasingly dependent upon electrical reliability, flexibility and maintenance. Only by the constant comparison of methods have present electrical standards been reached, and only by the continuation of this practice can future perfection be achieved.

Regardless of the industrial, commercial or residential purposes of a modern structure, current is essential for three services: light, heat and power. Homes, originally employing electricity solely for lighting, now use more than 50 percent of their total current consumption for ranges, water heaters, refrigeration, ironers, radios, clocks, toasters, dryers, fans and other appliances. Commercial buildings are likewise adding loads in the form of air conditioning, ventilation, refrigeration and other power-consuming equipment. Industrial service is mounting for motors, electric heating units, welding equipment and high level lighting.

To varying degrees, each installation demands that loads be carefully estimated, distribution scientifically planned and attention directed to such factors as voltage selection, voltage regulation and power factor correction.

Problems of design and selection of equipment have been lessened greatly by the trend towards *standardization*. With standardized current and motor characteristics, it is becoming increasingly possible to obtain manufacturing economies, interchange motors and equipment, and safeguard the investor by guaranteeing uniform ratings and capacities. Current is now generally fixed at 60 cycles. Voltage for residential and commercial structures with single phase lighting, small heating units and appliances is now generally standardized at either 115 or 120 volts and, in these structures, distribution also is becoming unified, with 3-wire secondary mains and either 2 or 3-wire services to customers. Industrial and large power loads are now generally supplied at 3-phase, and utilization voltages in common acceptance are at the levels of 230, 240, 460 and 480 volts. Since the majority of our motors are now rated at either 220 or 440-volts with a 10 percent permissible voltage variation, these voltage levels are generally satisfactory. To avoid the necessity for two separate supply lines, 3-phase 4-wire service is becoming increasingly common, with phase-to-phase connections for heavy equipment and phase-to-neutral connections for lighter loads.

But standardization does not by-pass the necessity for *analysis*. Among the first analytical checks to be made is an initial load survey. *Determination of load* is extremely important, since the size and number of primary and secondary substations, the size, number and arrangement of feeders, and the type of distribution system is directly affected by size, distribution and nature of the load. Seldom, if ever, are all loads known prior to the complete installation of a distribution system and, for this reason, exact load surveys are difficult to achieve. Distribution systems are often installed while equipment layout is in the formative stages. Altered production plans and availability of materials often alter the locations and sizes of machines being installed. Equipment such as air-conditioning compressors, fans, blowers or pumps may be added after installation has begun, and major changes are sometimes required.

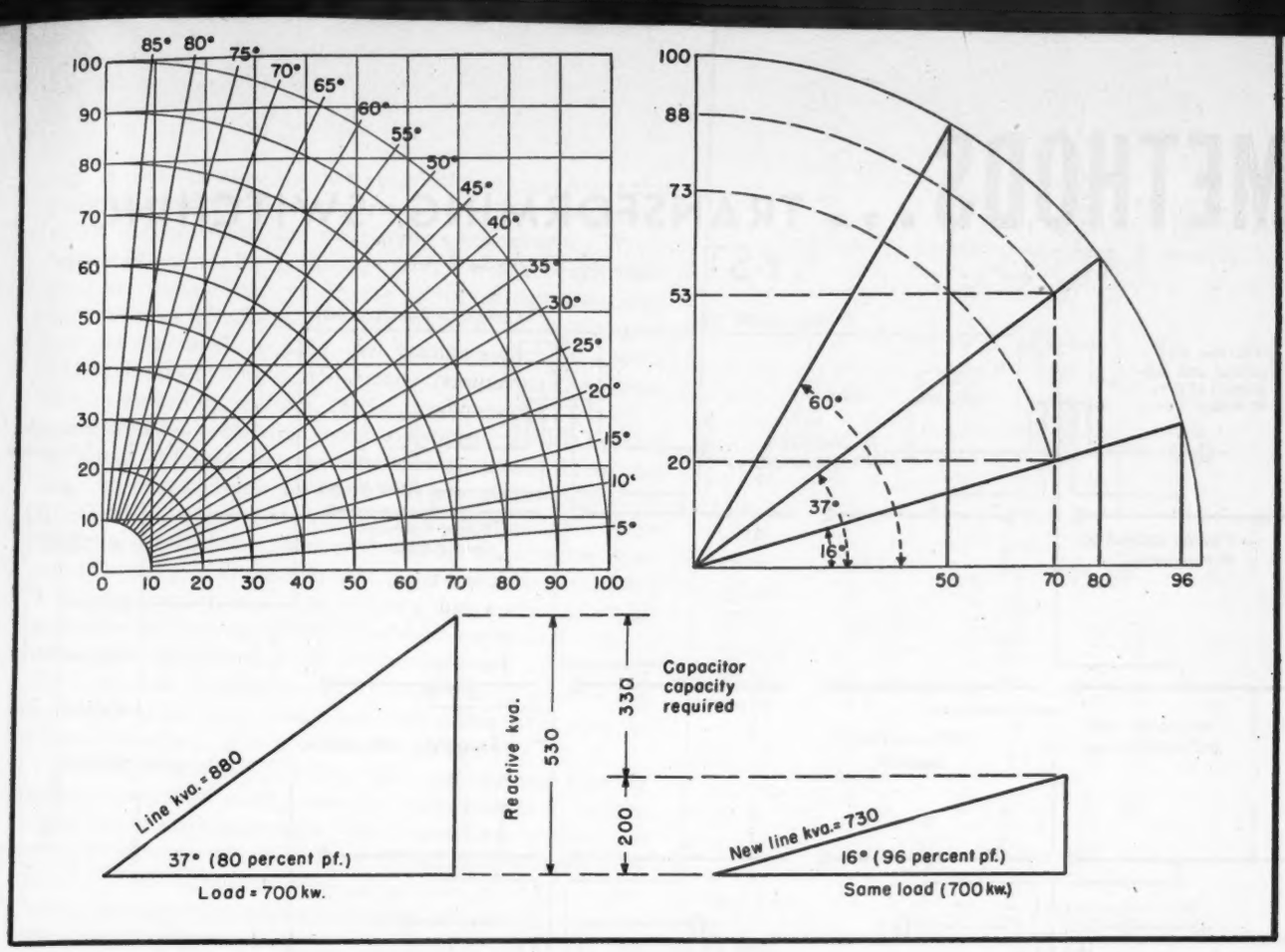
Such changes do not indicate lack of planning but rather reflect the constantly-changing economic and engineering thinking behind high-pressure competitive production.

Estimations for lighting are not an initial consideration, and current requirements can be closely computed knowing the floor areas, mounting heights for luminaires, spacing and location of roof trusses and columns, desired lighting intensities and type of illumination contemplated. For rapid estimates, some engineers use the approximate value of 3-watts/sq. ft. for fluorescent installations to deliver an average of 50 footcandles to working areas, and twice this value for an equivalent incandescent installation.

Power requirements for large motors, heating and furnace loads must be estimated separately, for their individual size and importance have a much greater influence on the system than a similar load created by numerous small motors. To determine the kva. demand for the entire plant, a complete listing of equipment is absolutely necessary, listing locations, magnitude and type of equipment. When this tabulation of equipment is completed, the probable demand can be closely estimated by considering the *demand factors, diversity factors* and *load factors.*

In selecting a distribution system, demand and diversity factors are of greater importance than load factor. For example, the size of a branch circuit is determined by multiplying the sum of the connected loads by the demand factor for these loads. Load-center capacity is determined by dividing the sum of the maximum branch demands by the diversity factor for these controlled branches. And the required transformer capacity is estimated by dividing the sum of the maximum load-circuit demands by the diversity

Synchronous Motor Characteristics	90 percent of Rated Voltage	110 percent of Rated Voltage
Speed: Full load	Decrease 1.5%	Increase 1.0%
Slip	Increase 23%	Decrease 17%
Efficiency:		
Full load	Decrease 2 pts.	Increase 1 pt.
Half load	Increase 2 pts.	Decrease 2 pts.
Starting torque	Decrease 19%	Increase 21%
Power factor:		
Full load	Increase 1 pt.	Decrease 3 pts.
Half load	Increase 5 pts.	Decrease 6 pts.
Current: Full load	Increase 11%	Decrease 7%
Starting	Decrease 12%	Increase 12%
Overload capacity	Decrease 19%	Increase 21%



VECTOR DIAGRAMS furnish clear pictures of many electrical problems. An example is the use of triangles to represent the magnitude of reactive and line kva. for fixed kw. loads with various power factors. Illustration indicates capacitors required to improve the pf. from 80 to 96 percent when the connected load is 700 kw.

factor for these supplied load circuits. Since demand and diversity factors cannot always be positively ascertained, it is general practice to use a diversity factor close to unity and to use larger demand factors than contemplated. While this will result in excess initial capacity, it introduces a safety factor and provides for reasonable plant expansion.

The *selection of primary and secondary voltages* deserves considerable study. To minimize distribution losses, these voltages, both in primary and secondary circuits, should be kept as high as possible. For economic reasons, primary voltages of 4160-v. and 13.2-kv. have wide acceptance for, generally speaking, these voltages can result in savings due to the use of less expensive switchgear, less copper or fewer primary circuits. For secondary industrial distribution, the trend is towards 460 volts, since standard equipment is available for this voltage, the distribution system is less expensive (compared with 230 or 208/120-volt systems), and incidental 120-volt loads can be supplied directly from these circuits by installing step-down transformers as required. Of course, when loads consist almost entirely of fractional horsepower motors and lighting, secondary circuits carrying 208/120-volt current are desirable.

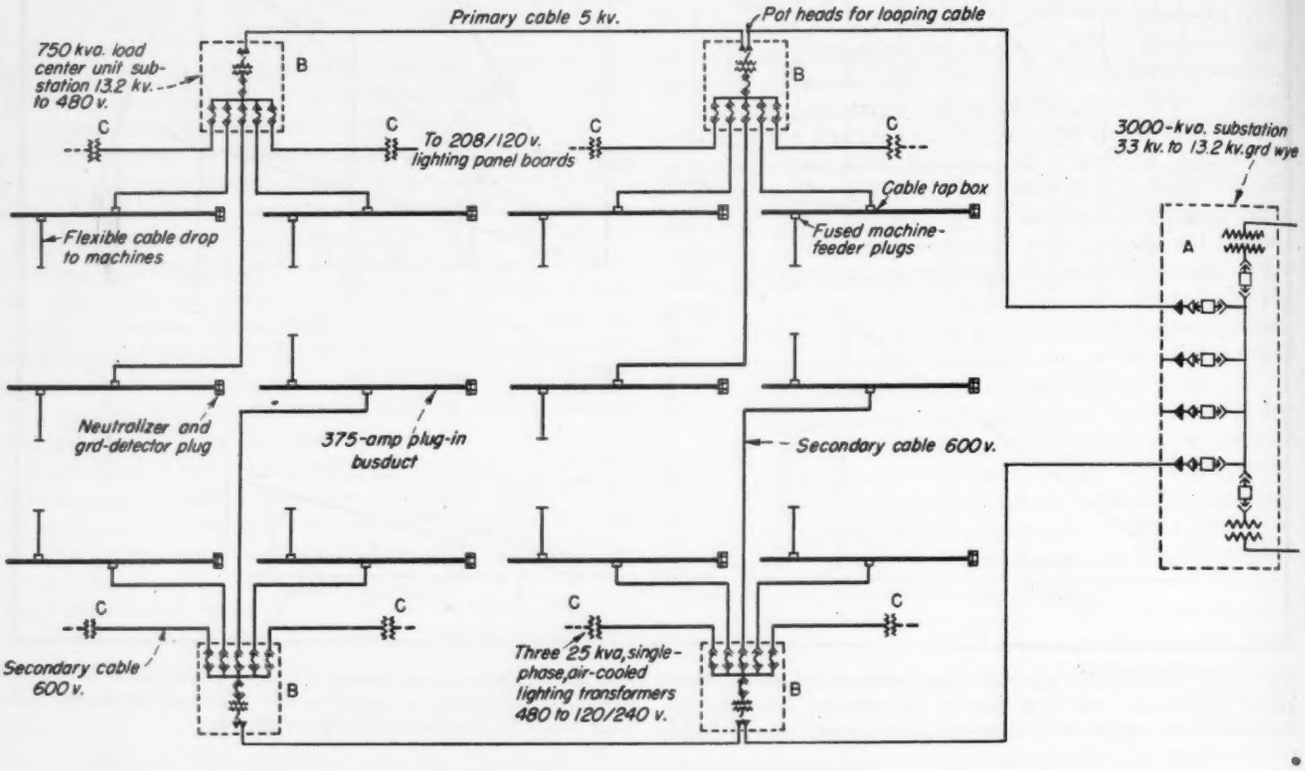
Provision for *voltage regulation* should be considered when estimating all new installations, for regulating equipment is definitely beneficial and installation at a later date is generally inconvenient, difficult and expensive. The importance of limiting voltage variations to from 3 to 5 percent (plus or minus nominal ratings) cannot be overemphasized, for electrical equipment is dependent upon constant voltage for maximum efficiency. As examples, variations for synchronous motors are tabulated.

Power factor, indicating the ratio of the load in watts to the actual volt-amperes carried on the lines to supply that load, must be taken into consideration in distribution layouts. This is evident since, with a high power factor, line current can be reduced and more effective use can be made of transmission, transformation and distribution facilities. When power factor improvement is by means of capacitors, capacitors should be located near the load, for efficiencies will then be carried all the way from the corrective equipment to the power source.

A useful method for obtaining clear visual pictures of electrical problems is through use of *vector diagrams.* The power factor problem (above) clearly demonstrates this application. Since power factor is the ratio of the connected load in watts divided by the line current in volt-amperes, it is apparent that a 50 percent pf. can be demonstrated by a right-angle triangle with an acute angle in the lower left corner of the chart equal to 60 degrees. Likewise, 80 percent pf. can be diagrammed when this acute angle is 37 degrees, and 96 percent pf. is apparent when the angle is 16 degrees.

By using these triangles and scaling the various sides, it is apparent that a 700-kw. connected load with an 80 percent pf. has a reactive kva. of 530 and it requires a line current of 880 kva. Likewise, the same connected load with a 96 percent pf. has a reactive kva. of 200. Therefore, if it is desired to estimate capacitor requirements for improving the pf. in this problem from 80 to 96 percent, the difference in reactive kva. is quickly scaled as 330 (rkva. capacitors required). The new line requirements are indicated to be 730 kva. This indicates a reduction of 150 kva.

METHODS... TRANSFORMING, SWITCHING


Primary cable 5 kv.
Pot heads for looping cable
750 kva. load center unit substation 13.2 kv. to 480 v.
B
C
To 208/120 v. lighting panel boards
3000-kva. substation 33 kv. to 13.2 kv. grd wye
A
Cable tap box
Fused machine-feeder plugs
Flexible cable drop to machines
Neutrolizer and grd-detector plug
375-amp plug-in busduct
Secondary cable 600 v.
Secondary cable 600 v.
Three 25 kva, single-phase, air-cooled lighting transformers 480 to 120/240 v.

TYPICAL DISTRIBUTION system for medium-size industrial plant shows simple radial installation with main 3000-kva. outdoor substation for transforming 33-kv. utility service to 13.2 kv. (A), separate 750-kva. indoor load-center unit substations for transforming current to secondary level of 480-v. (B), and single-phase air-cooled 25-kva. lighting transformers for 120/240-v. service within the plant.

DEPENDING upon size and characteristics of industrial plant and utility service, current is supplied either directly at utilization voltage or is stepped down once or more times for local distribution and eventual application through primary substations (with primary voltages above 15 kv. and low-side voltages between 15 and 2.4-kv.) and secondary substations (reducing voltage levels from the 15-to-2.4-kv. range to 600 volts or less).

High voltage switching involves many factors which have a direct bearing on the selection of equipment. Briefly, these factors include supply voltage, size of load to be served, necessity for service continuity, the need for duplicate services, distance from substation to plant, short-circuit kva. for utility and plant, service available, types of utility relays, number of step-down transformers contemplated, amount of flexibility desired, and the amount of the investment.

High-tension bus arrangements therefore vary widely, depending upon the utilization of a single or multiple utility service, one or several transformers in parallel, and various combinations of breakers, switches or fuses. In many plants, a single supply and a single transformer are entirely satisfactory, with breakers, switches and fuses installed in accordance with specific requirements of utility procedure, plant requirements or code demands.

With two or more utility services supplying current to a common bus system, primary voltage can be carried directly to load centers, or one or more transformers can be connected to the primary bus in parallel. Either breakers, fuses or disconnects may be used as circuit opening devices on transformers, but breakers are to be preferred and are frequently required on the low-tension side even when fuses or disconnects are installed. When bus-sectionalizing breakers are practicable, transformer high-tension breakers may be eliminated.

Primary substations fall into two broad classifications: those serving only as switching stations and those where voltage transformation takes place. While the ideal location for either classification would normally be at the center of plant load, practical considerations frequently locate the station near property lines, with either overhead or underground feeders running to secondary transformers within the plant area. Even in the details connected with the installation of these feeders, there are considerations to be reviewed. For example, overhead lines should be kept above the reach of cranes and other mobile equipment, they should be safely supported at a safe clearance height when crossing above buildings, they should be kept at a distance from cooling towers to prevent ice formation on lines during winter months, and they should avoid chemical and cement plants to prevent deposits on insulators or bushings.

Location of substations also suggest analysis of indoor and outdoor facilities. Indoor substations have the advan-

tage of protection against dirt, chemical dusts and fumes that promote deterioration of equipment. Indoor installations utilize less expensive and more compact equipment. Working conditions are better during extreme weather conditions. However, indoor stations require an investment in a building and other compensating factors also exist, so that general practice tends to place low voltage switching (below 13.8 kv.) indoors and locate primary transformers and high-tension switching stations in the open.

Methods for *protecting transformers* and circuits against fault and overload overcurrents include power fuses and both air or oil circuit breakers. While an installation of fuses and disconnects is generally less expensive, there are limitations in their use, such as the hazard of changing fuses at high voltage and the fact that failure of a single fuse in a 3-phase circuit results in single-phase operation of all connected motors, a condition which may cause definite damage to equipment. Circuit breakers are considerably safer for, with breakers properly installed, circuits can be switched under any conditions and, since they can be tripped by relays, close protection is obtainable.

Modern induction-type relays with instantaneous tripping attachments fulfill most protective requirements. Adjustments can be made to cover a wide range of applications and relay settings can be coordinated so that they will trip only when desired. Where extreme accuracy is of prime importance, characteristics of transformers are considered when selection of relays is made.

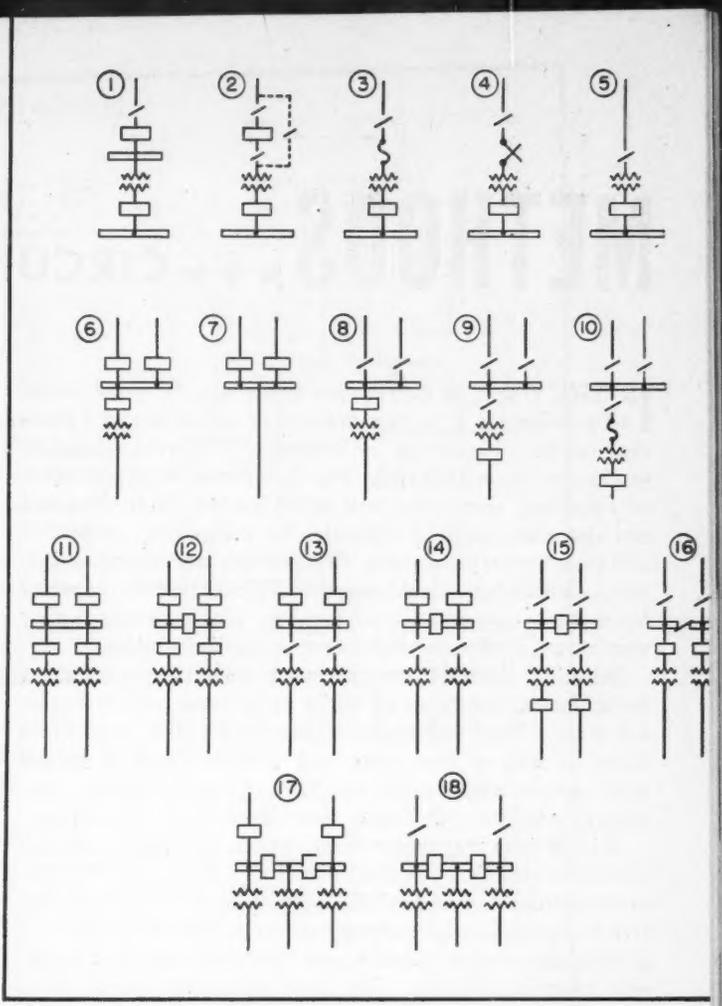
To protect systems against possible damage resulting from either short circuits or overloads, automatic relay equipment and fuses should be provided. There should also be provision for disconnecting plant substations from utility lines in case of trouble which could affect the main service.

Cooling of transformers takes several forms, units being either self cooled, water cooled, or cooled by either forced air or by a combination of forced oil and forced air. Due to simplicity and lack of moving parts, self cooled transformers are in wide use. Water cooling is usually limited to indoor installations. The use of forced cooling is limited to relatively large 3-phase units. Since added capacity is obtainable, a margin of safety for overloads and peak demands can be secured at slight additional cost.

More and more consistently in new industrial plants, primary substations are being constructed with *factory-assembled metal-enclosed switchgear* for feeder protection and switching. Including meters, relays, current and potential transformers, busses and breakers, this switchgear is completely assembled, wired and mounted in self-supporting metal enclosures. Since all live circuits are enclosed in grounded metal, indoor vaults or outdoor protective fencing is unnecessary.

When special designing is required, *open framework* switching equipment is assembled in the field. While a field-assembled substation has the same basic components as the factory-assembled unit (relays, breakers, meters, transformers, etc.), all assembly work and wiring is completed at the selected substation location. In designing open framework switchgear, spacing and facilities for testing must be provided. Space is particularly important for proper clearances between busses and for the installation of disconnecting switches.

When transformers and primary feeder switchgear is assembled in a single unit, the installation is referred to as a *unit substation.* Coordinated and assembled at the factory, the unit includes equipment for voltage transformation, automatic voltage regulation, feeder switching, metering and protection. Incoming high-voltage circuits may be either underground or overhead. Terminal provisions exist for both. Voltage is stepped down to plant distribution or utilization level by 3-phase, oil or Askarel-insulated, self-cooled transformers.



PRIMARY SWITCHING equipment depends upon utility voltage, desired continuity of service, number of transformers, size of plant load, economic considerations and similar factors. As these factors vary, so, also, does equipment arrangement. The single-line diagrams above indicate various equipment arrangements for plants having one or more supply lines; one, two or three transformer banks; circuit breakers, disconnects and fuses.

Standard automatic control equipment includes line-drop compensation for maintaining desired load-center voltage. Substation output is controlled by an encased switching section, assembled on a common channel base, encased in a weatherproof housing, and equipped with front and rear access doors. Instruments are mounted on front panels for both indicating and recording current characteristics.

Secondary substations (low voltage ratings below 600 volts) are located nearer to centers of load, are fed from feeders from primary substations, step primary voltage to application level, and control feeders carrying this voltage through the plant. In general, maximum ratings for secondary substations with 480-volt secondaries are 1000 kva. (3 phase). With 240-volt or 208/120-volt secondaries, optimum ratings seldom exceed 500 kva.

Load center unit substations are completely metal enclosed, coordinated assemblies having proper switching, controlling and terminating equipment for the incoming high-tension line; a transformation section for stepping primary voltage to either 600, 480, 240, or 208Y/120 volts; and terminals and controls for secondary feeders.

METHODS... CIRCUIT ARRANGEMENTS

IN THE design of distribution systems, it is sound policy to provide for a certain amount of expansion and rearrangement. Flexibility is imperative where changes in production are anticipated. For the shifting of departments or relocating operations will affect loading of feeders and can also alter required capacities for controlling, protective and transformer equipment. To provide for normal expansion, switchgear should have sufficient reserve capacity for a reasonable addition of breakers without necessitating shutdowns, feeder reinforcement or similar problems.

Selecting electrical equipment or deciding upon circuit arrangements solely on an initial price basis is an economical error. For long-range economics includes capitalized losses as well as first costs, and dividends will be gained with systems that furnish adequate delivered voltage, simplicity, reliability, flexibility and maintenance provisions.

It is obvious that these objectives are important, yet each should be considered in the light of all related requirements and conditions. For example, service continuity is imperative in hospitals where outages affect health and safety. It is also important in plants where shutdowns result in extensive material spoilage. But cases also exist where short outages merely would result in inconvenience and, in such instances, there is slight justification for installing an infallible power supply. Reliability of utility and generation services also must be considered, for there is little wisdom in establishing complete reliability within plants fed by sources subject to frequent interruptions. In determining adequacy and reliability of power sources, considerations range from station capacity to utility distribution details, such as relative merits of primary overhead-radial and underground-network systems. While faults occur less frequently in underground systems, breaks in overhead circuits can more quickly be located and repaired.

While each major arrangement can be varied to satisfy local requirements and changing loads, industrial distribution systems can be broadly divided into two typical classifications: radial and network. Radial systems can be further listed as simple, loop primary, banked secondary, primary or secondary selective. Network systems can be either simple, spot, or primary selective.

Only until recently, the *simple radial* arrangement was a prevalent industrial distribution installation, employing a single substation, a main switchboard, low voltage feeders to load centers and secondary feeders to local switchgear for controlling motors, heating, lighting and other plant loads. With a single substation and low voltage bus, full advantage could be taken of load center diversity. However, the use of copper was high, switchgear was relatively expensive, voltage regulation was often non-uniform, and a fault on the main bus could result in the outage of the entire system. Generally speaking, this system is used principally for small plants where demands are 1000 kva. or less.

An improved version of the simple radial system carries power to load centers at primary voltage where, at these local areas, separate transformers step current to utilization voltages. Because of higher distribution voltages, losses are reduced, regulation is improved and copper requirements are materially lessened. Although the total expense for transformers is increased, the mentioned advantages as well as the elimination of a main switchboard generally result in overall savings of investment. A disadvantage lies in the fact that, in order to utilize economical primary layouts, several transformers are usually connected to each primary feeder and a fault in any feeder results in the outage of several load centers.

The *loop primary radial* circuit employs a primary sectionalized loop, controlled by a single primary feeder breaker and auxiliary primary breakers at each transformer section. Should a fault occur in any section of the loop, the main breaker opens but can be reclosed to continue general service as soon as auxiliary breakers are opened to segregate the faulty section.

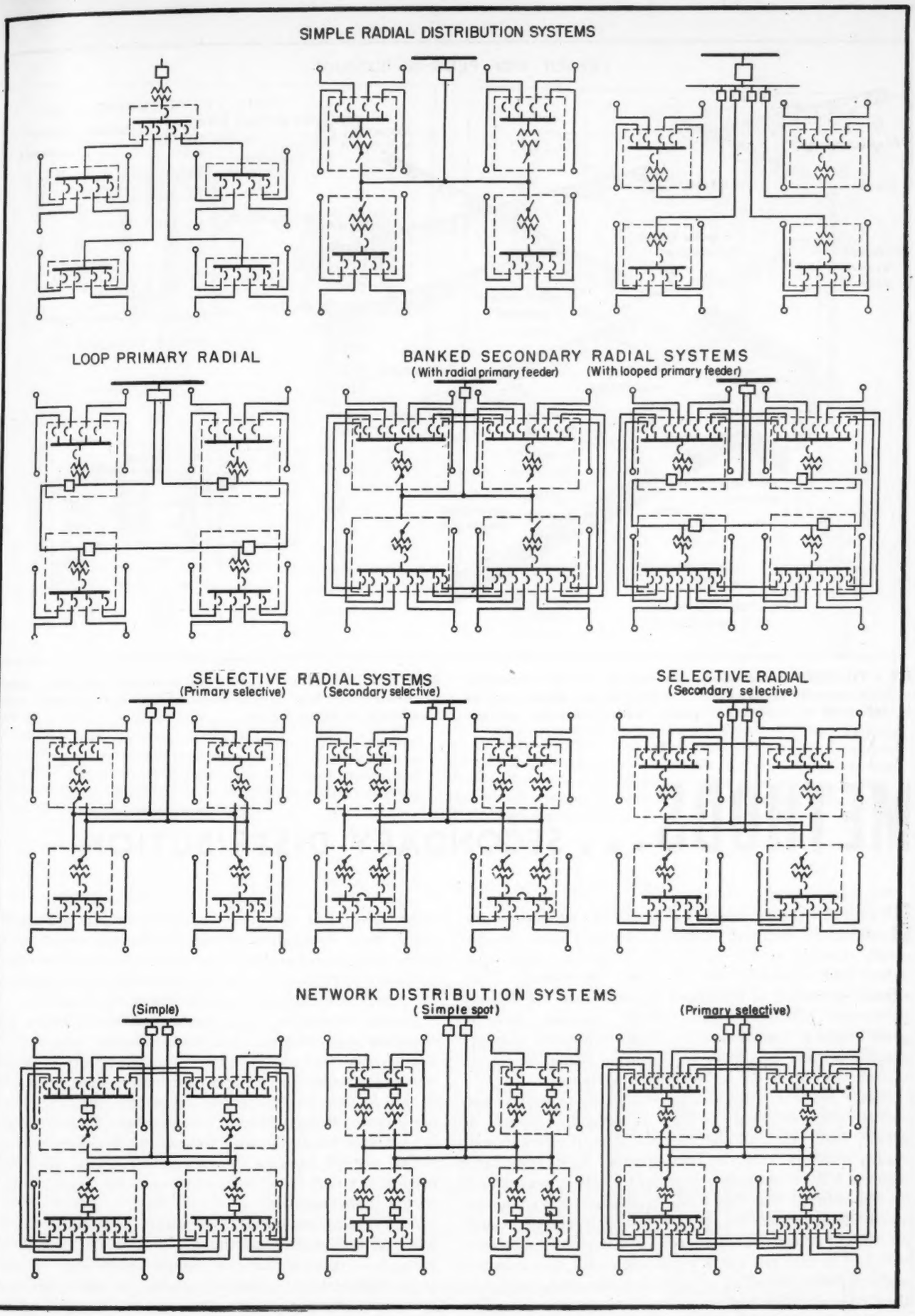
Another recommended layout is the *banked secondary radial* arrangement, in which transformers are fed by a single primary feeder or loop, while secondary connections link the separate transformers together in parallel. With either arrangement (single feeder or loop), a faulty transformer can be dropped from the system for repairs or replacement while temporary connections are established through the connecting secondary loop. While capacities of transformers should be sufficient to prevent extreme overloads under these conditions, the secondary loop tends to equalize loading and critical estimations for individual load center transformer capacities become less important. Economically, the added cost of secondary loops and additional switching equipment can be offset by smaller transformers.

A *primary selective radial* arrangement is achieved by installing two primary feeders, each with a capacity for feeding the entire system and with half of the transformers normally fed from each primary feeder. Local transfer or selector switches make it possible to switch transformers to either feeder if faults or overloads develop.

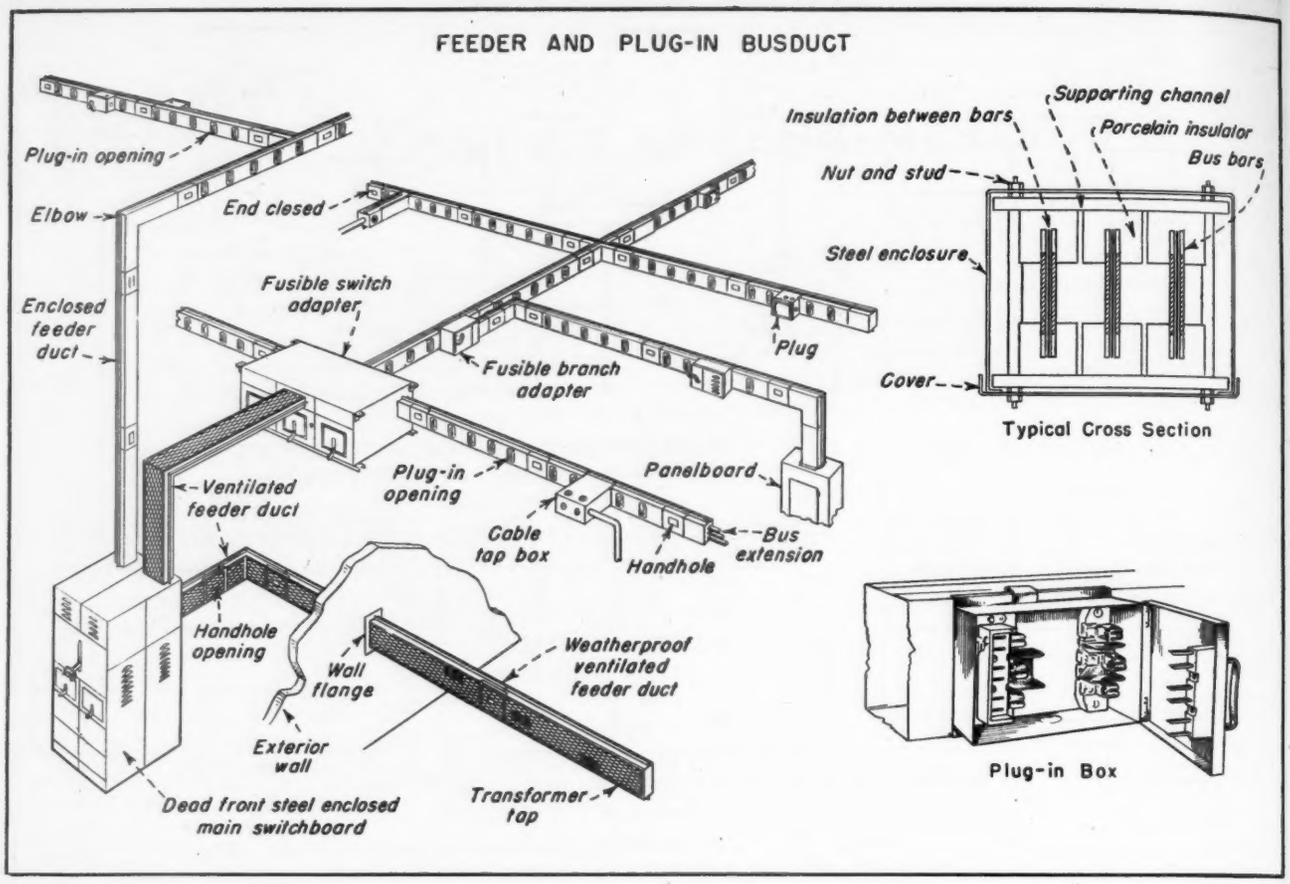
In a *secondary selective radial* system, this feature of selectivity can be incorporated by installing multiple transformers at each load center with switches placed between transformers and secondary busses. Bus tie breakers, open during normal operation, make it possible to connect the two secondary bus sections of each load center when conditions merit.

Many features of the various radial systems are carried into network layouts, the *simple network* combining the advantages of carrying primary voltage to load centers, utilizing multiple primary feeders and maintaining secondary loops between the low voltage busses of adjacent substations. This results in considerable excess feeder and transformer capacity in small plants where only a few primary feeders are required, but this excess becomes fairly small in large plants demanding six or more feeders. The principal advantage of a simple network over any of the radial systems lies in the complete continuity of service, since faults are automatically segregated and the necessity for manual switching is eliminated.

A slightly different form of the simple network, known as the *spot network*, can be obtained by installing two transformers in parallel at each substation, connected to a single secondary bus. Thus, a fault in either primary feeder or any transformer will not interrupt service.



THE SELECTION of secondary distribution systems depends upon equipment layout, size and importance of motors, desired reliability of service and provisions for flexibility. These objectives can be obtained by the judicious selection of a radial or network system fulfilling the requirements of the specific plant.



BY UTILIZING a secondary distribution system consisting of high capacity feeder ducts and plug-in bus ducts, current is delivered to utilization points with minimum voltage drop and line losses. Variety of accessory sections, types of construction and arrangement of bus bars permits wide flexibility in plant layout.

METHODS... SECONDARY DISTRIBUTION

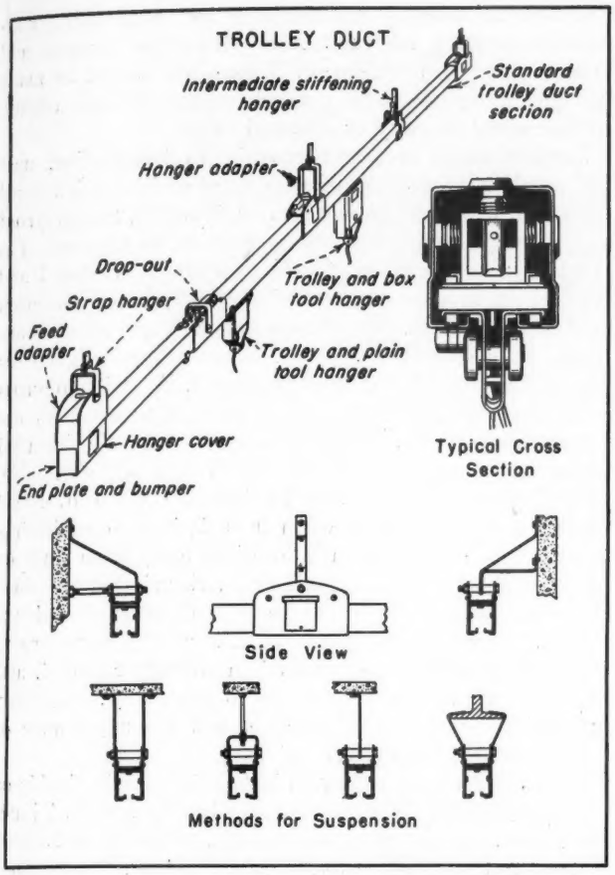
BETWEEN feeder breakers of secondary substations and utilization locations, numerous methods exist for efficiently carrying current. In all cases, *minimum voltage drop, safety and reliability are of prime importance.* Since efficient operation of equipment depends upon the delivery of current having adequate voltage, secondary runs of great length or limited capacity should be avoided wherever practicable, and maximum voltage drop should be limited to from 3 to 5 percent for acceptable operation.

Safety includes protection for equipment as well as personnel, since secondary wiring is generally exposed to grease, water, dirt, oil and mechanical injuries which may readily result in faults or short circuits. Strict compliance with the NEC is absolutely essential for safety, but it should be remembered that the NEC establishes only minimum standards and, therefore, a safe system is not necessarily an efficient or convenient system. For maximum efficiency, it is well to carefully check requirements for all conductors and equipment, installing greater capacities than directed by the Code whenever borderline cases are encountered. Also in connection with safety, reliable grounds for all interior wiring are essential.

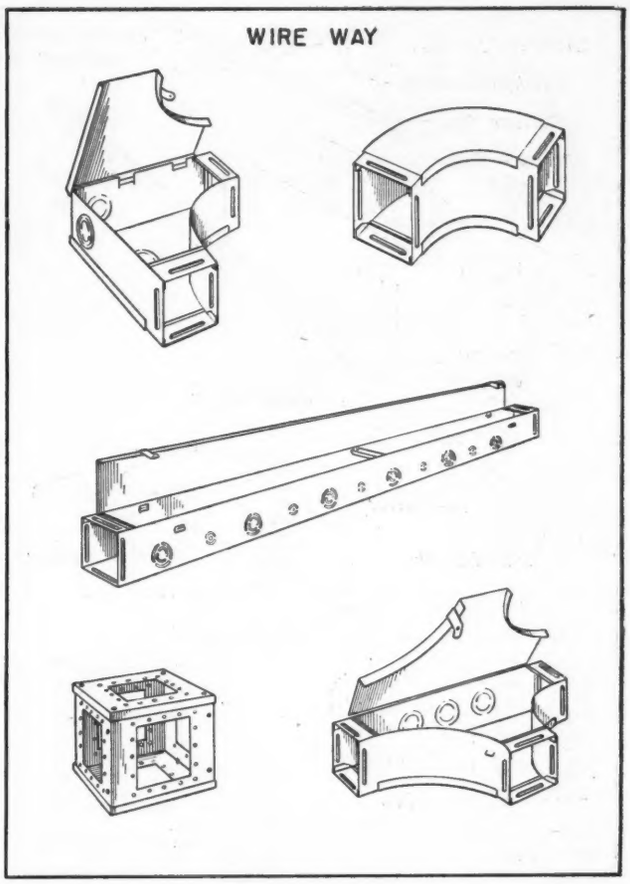
Reliability depends greatly upon the main distribution system of a plant, for, whereas branch circuits are usually radial, main distribution systems can include variations of either radial or network arrangements. Only in cases where reliability is paramount, such as for emergency lighting or fire pumps, are duplicate branch circuits recommended.

Normal expansion, rearrangement of departments, and changing loads demand that a distribution system have *flexibility* as well as spare capacity. Flexibility is fundamentally a problem of general distribution, since provisions to shift loads at control centers are of little assistance when the overall system cannot accommodate these changes. It is largely due to the requirements for flexibility that the varied use of busways, wireways, underfloor raceways, open-wire circuits and numerous means for branch circuit wiring is advocated.

Busways, or bus ducts, carry bare conductors supported by insulators within metal enclosures, either completely encased or perforated for maximum ventilation. In most large plants where traveling cranes or other overhead operations are not present, busways can be used advantageously and, in these locations, maximum current can be delivered to the various load centers with minimum voltage drop. Standard ten-foot sections and a wide selection of



TROLLEY DUCT is widely acceptable where portable tools and moving loads prevail. With current-carrying bus bars protected by a bottom-slotted duct, safety and cleanliness of contacts are at a maximum. Since trolleys move with the job, extension chords can be shortened without restricting the freedom of worker movement.



WIREWAYS, prefabricated metallic troughs for carrying conductors, can be used advantageously in dry locations free from corrosive fumes. A wide variety of straight sections and accessory fittings of varying shapes, cross sections and metal gauges, provide wide selection and give ample protection to conductors.

elbows, cross-overs, tees, plugs, expansion joints, flange connections and tap boxes make it possible to design systems that can solve most structural or routing problems. Ratings run from 50 to 5000 amperes, at 600 volts and less, for single or 3-phase service as well as for 3-phase 4-wire systems.

Busways are available in three types: plug-in, feeder and trolley. Each type has specific applications and they will render excellent service when properly selected and installed. For best layouts, certain general methods should be followed. Only standard fittings should be used. Current ratings should be selected for maximum practical loadings. Parallel runs of low capacity should be preferred to a single heavy-duty bus. Busses should be tapered as loads are reduced along the runs. Low power factors should be corrected by the judicial installation of capacitors in the busway runs.

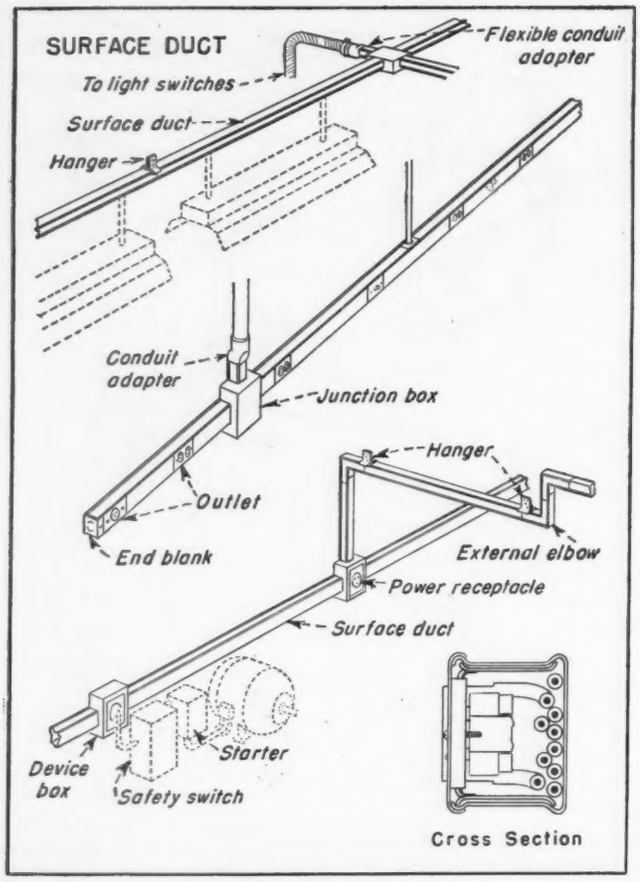
Plug-in busways furnish closely-spaced outlets along the length of runs, permitting the establishment of convenient connections at any desired point and the corresponding reduction of the lengths of individual branch runs to equipment. Plug-in devices include switches, ground indicators, capacitor plugs, circuit breakers and static voltage protectors. Standard ratings are 600, 400 and 250 amps.

Generally, *feeder busways* are of higher capacity than plug-in systems and are designed to connect transformers to plug-in runs or switchboards, and connect switchboards to plug-in runs or load-center panelboards. Although feeder busducts are primarily designed to carry current from one point to another, rather than feed many closely-spaced branch connections, it is possible to establish load taps at joints between any two standard sections.

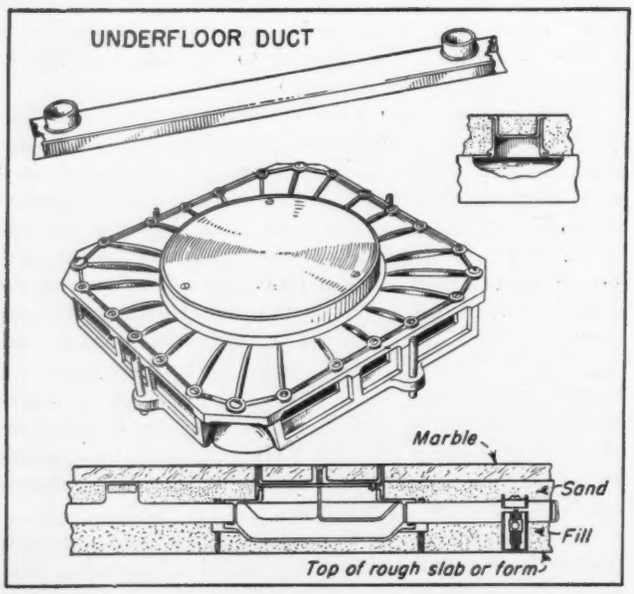
Trolley busways permit the use of trolley-type connection devices and thus establish the possibility of movable receptacles and service outlets. Users of power tools and other electrical equipment are thereby given more freedom of movement, and they can move along a production line or working area with their power connection always present. Flexible cables connect tools and other loads to the trolleys moving on rollers within the busways. Contact between trolleys and protected busbars is by brush or contact rollers. Trolley busways have also proved useful for lighting installations, since any desired location of fixture can be established by shifting units along the busway line. Heavy-duty 3-phase 100-amp. trolley busways are available for power tools and moving loads, while units of 50-amperes can be secured for lighter loads.

Wireways are similar to busways in that they consist of prefabricated metallic troughs supported at intervals. However, loose insulated conductors replace the use of bus bars. Wireways are used for exposed work in dry locations where not subject to mechanical abuse or corrosive fumes. They are not recommended for hazardous locations or in storage battery rooms or hoistways.

When wireways are grounded, all joints must be bonded.



SURFACE METAL RACEWAYS are installed quickly, permit ready access to conductors, provide ample mechanical protection, can be salvaged for reuse, are tamper proof and, when painted to conform with background, are neat and unnoticeable. Outlets can be installed where required, providing convenient receptacles for many applications.



UNDERFLOOR DISTRIBUTION systems of metal or fiber provide a flexible network for areas where wide aisles, open bays, high ceilings or functional use of the area discourages the use of overhead or visible ducts and conduits for carrying power, light, phone or signal conductors. Ducts are available in single or multiple runs.

Standard accessories are available for establishing connections between the conductors within the wireway and branch circuits to equipment. Extensions should be made in rigid or flexible metal conduit, electric metallic tubing, surface metal raceway or armored cable.

Surface metal raceways provide an inexpensive, neat and simple method for running exposed wiring. It is rugged enough to withstand normal service, it is safe, tamper-proof and, when painted in conformity with the background, it is practically unnoticeable. Conductors can be removed and replaced in varying numbers, sizes and types of insulation as demands change. Installation is simple and changes are rapid. Like wireways, surface raceways are designed for dry locations free from corrosive vapors. A variety of cross sections, accessory fittings, sizes and gages make its use extremely versatile. Plug-in adapters can be installed wherever desired so that outlets are conveniently obtainable.

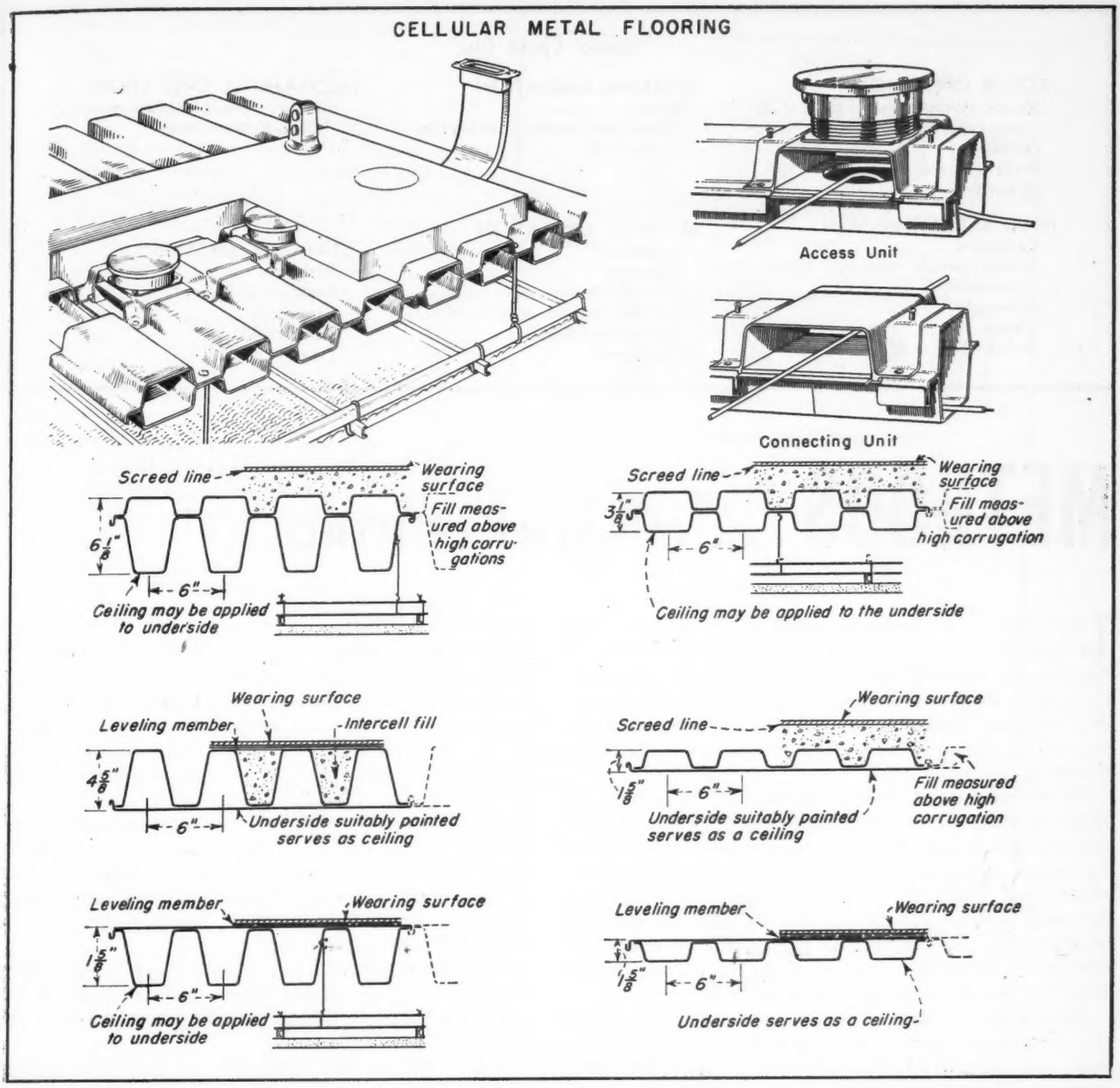
Underfloor raceways can be installed when overhead clearance is required, or when it is desired to establish a flexible floor-outlet system in locations away from walls or surrounded by aisles. In such cases, electrical connections above the floor level would be both obstructive and unsightly. To anticipate expansion, it is usually necessary to install more wiring space than is absolutely essential, and first costs are relatively high due to this factor. However, mechanical protection is excellent and the appearance of the area is clean and free.

Underfloor raceways can be installed as single, double or triple compartments, all three types having standard junction boxes. In this way, power, light, telephone and signal systems can be confined to separate channels. Connections of floor outlets can be made directly into underfloor channels, or rigid conduit branches can be run from special junction boxes. Floor outlets can be established in accordance with a pre-installation pattern and can be either located for use or covered as requirements are altered. Raceways can be secured both in metal and fiber. They can be buried in concrete or floor fill, set flush with woodblock or cement floor coevring, or covered by linoleum or similar surfacing material.

Floor distribution can also be obtained in buildings where *cellular metal flooring* is used as an element of construction. Where such construction exists, electrical conductors can be placed in the hollow spaces of the metal floor framework and adjacent channels can be used for lighting, power and signalling wiring. Outlets can be established or abandoned as demand varies. Cellular units, extending from beam to beam, can be welded or bolted at supporting points, and their shape and gage can be altered to fit local design and loading conditions. When erected, cellular metal flooring has the general appearance of being deeply and sharply corrugated. Wiring can be placed in the troughs opening either upwards or downwards and outlets can be in the floor above or in the ceiling below.

The bulk of our industrial distribution, however, is in *rigid metal conduit,* which provides excellent protection to conductors, can be installed exposed or concealed in floor slabs or behind suspended ceilings, provides dependable and protective grounding, and can be used under all atmospheric conditions. Depending upon local conditions, either black or galvanized rigid metal conduit can be used.

Where lighter conduit is permissible, *electrical metallic thin-wall* tubing can be considered advantageously. Similar to rigid conduit but weighing approximately a third less per unit of length, it offers complete mechanical protection without being as mechanically sturdy as rigid conduit. Since



WIRING CAN BE CONTAINED in floor channels when cellular metal flooring is part of the building construction. Accessories, taps and outlets fit many floor and ceiling power and service requirements. Cellular flooring can be obtained in numerous designs to conform with structural or electrical plans of the building.

thin-wall tubing has insufficient stock for cutting threads, compression-type joints are used to connect tubing and fittings. Non-corrosive tubing and fittings are available in locations where corrosive fumes are present, and the variety of fittings is as complete as for rigid metal conduit.

Where vibration exists, where slight movement of equipment is involved, or where short extensions or temporary connections are required, *flexible metal conduit* supplies a definite need. Like the rigid conduit, flexible conduit provides a metallic enclosure for branch wiring.

In the same manner that thin-wall tubing is related to rigid metal conduit, *armored cable* is related to flexible metal conduit. Although its principal application is residential wiring, it has many industrial uses. It is not as strong, either mechanically or electrically, as metal conduit, and it is definitely not a raceway where conductors can be inserted or removed. The conductors are permanently installed. Conductors have a variety of insulations and the cable finish is also varied to meet the demands of general and special installations.

Overhead open wiring on porcelain insulators is the simplest and most economical method for wiring and it provides the same flexibility as overhead busways. Open wiring is readily accessible for inspection, extensions and alterations. Heat is rapidly dissipated due to the surrounding air, and greater current-carrying capacities are possible for this reason. However, extreme caution must be exercised in selecting locations for open wiring, for mechanical protection for this means of distribution is at a minimum.

Also worthy of a note are the various distribution paths, such as trenches in floors, covered by grids or plates; underground duct systems of pre-cast transite or concrete; cable racks on the sides of walk-through tunnels, and various exterior, overhead installations.

Control Check List

MOTOR OPERATION
- Relays (timing, induction disc or cup types)
- Valves
- Brakes (shoe or disc)
- Rheostats

MAGNETIC OPERATION
- Contactors
- Relays (simple magnetic, timing, overcurrent)
- Solenoids
- Valves
- Brakes (shoe or disc)

THERMAL OPERATION
- Relays
- Thermostats (bimetallic or expanding fluid)

MANUAL OPERATION
- Contactors
- Rheostats
- Starters (full or reduced voltage)
- Switches (master, selector, knife)
- Controllers (drum)
- Pushbuttons

MECHANICAL OPERATION
- Switches (limit, speed-sensitive, float, flow pressure)

STATIC ACCESSORIES
- Resistors
- Rectifiers (dry type)
- Capacitors
- Transformers
- Fuses

METHODS... CURRENT CONTROL

THROUGHOUT the entire scope of distribution, from generation to utilization, the necessity for *control* is constantly present. Either manual or automatic, remote or at the point of operation, control is essential for connecting disconnecting, combining and transferring circuits, adjusting and regulating current characteristics, and protecting equipment and personnel.

All mediums which produce motion, such as magnetism, liquid pressure, vacuum or gas expansion, are incorporated into mechanical controls, familiar applications including the thermostat operating on temperature changes, the photoelectric cell operating on light impulses, the microphone operating on sound vibrations, and the solenoid operating on magnetism. In combination with electronic relays and devices, these impulses are amplified to the extent where heavy equipment can be operated by a slight touch.

Since electrical devices depend upon reliable *contacts*, the selection of contacts which are resistant to corrosion and overheating has a definite bearing on the operation of controls. And, since sticking mechanical locking, or the welding together of contacts can result in severe circuit damage, contacts must have the ability to properly open and close the circuit when required, carry continuous current without overheating, and open the circuit without excess erosion or pitting. Ease of replacement is also important. Depending upon application, contacts range from mercury to tungsten, molybdenum, platinum, silver, copper, bronze or carbon. Each metal has its specific task. For example, arcing tips made from high-refractory metal carry little current but are selected to withstand the arc while the circuit is being opened. Their use is illustrated on air circuit breakers having multiple-stage contact arrangements. While the main contact carries the load, the second stage or auxiliary arcing contacts serve to protect the main contact from pitting.

Considerable thought has been devoted to the *suppression of arcs* resulting from relatively slow separation of contacts carrying high voltage current. *Speed* in breaking contacts is obtained by the use of springs or by opening the circuit simultaneously at several points. Small currents can be cleanly interrupted by mercury contacts in a vacuum, a method which is used as the basic principle of the familiar mercury-contact switch. Arcs also can be quickly broken by *increasing the resistance* of the gap between contacts. Such reasoning lies behind the magnetic "blowout coil" in which a magnetic field surrounds the gap to distort or lengthen the arc as contacts are separated. Other arc-suppression methods include the use of special oils, condensers, "deion" breakers and "horn gaps".

Control equipment falls into two broad classifications: *switching and regulating*. In the same class as switches are relays and contactors, while rheostats, resistors, reactors and compensators more commonly are listed as regulating controls. Certain types of controls, mainly in the electronic field, fulfill both requirements.

While *standard switches* range from single to 4-pole units with either single or double throws, other switches control more than two circuits and include controllers and voltmeter switches.

Knife switches, used principally for industrial applications, should have no place outside of a switchboard enclosure where experienced operators are in charge. More widely used are enclosed safety switches which are available in a wide range of sizes, capacities and varieties. In addition to the protection offered by metal enclosures, doors may be interlocked so that switches and doors are opened simultaneously. Enclosed switches are available with or without fuse holders and can be combined in the same housing with circuit breakers, relays or contactors for the manual or automatic control of motors or other equipment.

Switches can be listed in a number of ways. By purpose, they include service-entrance, disconnecting and high-voltage air-break units as examples. By use, they are listed as indoor, outdoor, bus-break, etc. In construction, they can be listed as open, enclosed, double-pole, vertical, horn-gap, fused disconnecting and so on. By method of operation, they can be spring-trip overload, remote or hook-stick.

Enclosed drum switches offer a convenient means of control since they are compact and have definite operating positions. A modification of the drum switch is the rotating-cam switch which employs a cam, mounted on a rotary shaft, designed to close pairs of stationary contacts.

Pushbutton switches provide the means for control through momentary contact. Such switches contain mechanical springs for holding contacts in the desired position until changed by the operator. Combinations can be selected so that contacts are normally open, normally closed, or held in either position just as long as pressure is maintained.

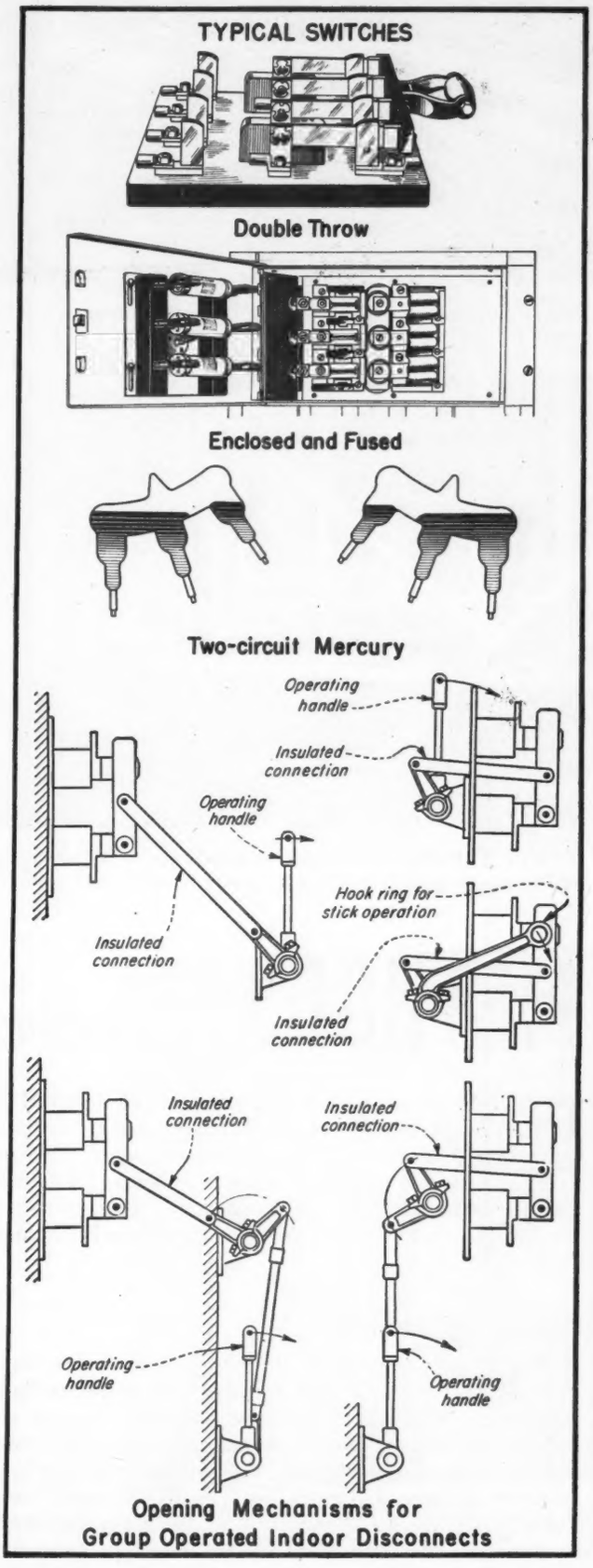
Automatic control of circuits at predetermined intervals may be obtained with time switches, consisting of clock mechanisms and sets of contacts. Such switches are advantageously used for activating street lighting circuits, display windows and heating units. These switches can be either electrically or spring operated, can have either standard 24-hour dials or astronomic dials that automatically adjust the moments of operation to coincide with either daily sunrise or sunset hours, they can be tripped manually when desired, and they can be secured in a variety of mountings, housings and ratings.

Control equipment, such as resistors and rheostats, demand conductors of high resistance with stability to withstand wide temperature ranges. *Resistors,* as fixed units of resistance, are employed to limit current in control equipment, and usually form part of rheostats and regulators. The most common form of resistor is alloy resistance wire wound upon a hollow cylinder of refractory material and covered with hard vitreous enamel to protect the wire from moisture or acids, to conduct heat away from the coils, and to equalize mechanical strains occurring with changes in temperature.

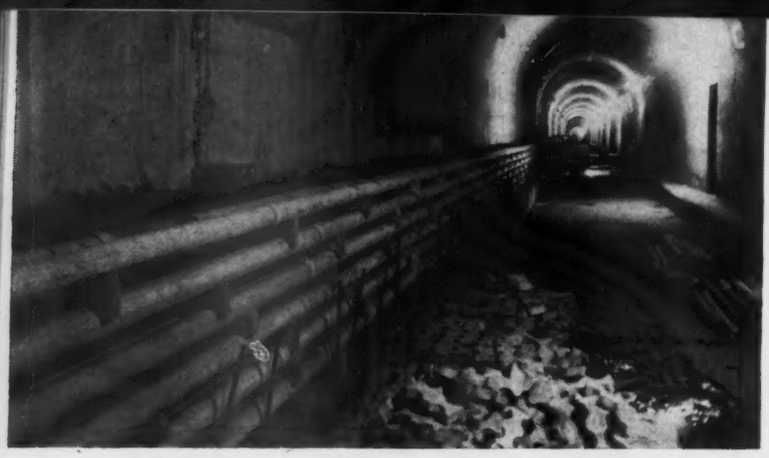
To change resistance in circuits, use is made of the *rheostat* which employs such resistance materials as wires, grids, liquids or carbon discs, so arranged that they can be placed in an electrical circuit for control purposes. To meet various control purposes, several types are available. The field rheostat, controlled by either handle or lever, consists of numerous contacts electrically connected with resistance wire embedded in vitreous enamel. Current carrying capacities are dependent upon the cooling surfaces and the temperature of the surrounding air. Other types of rheostats are the ring, slide-wire, carbon and wire-frame units.

Practical solutions to many industrial control problems can be obtained through the use of *relays.* Like other electrical equipment, relays can be classified in several ways. Construction features vary from remote control, plunger, induction and solenoid. Application designations include field, protective, underload and overload relays. Methods in operation vary from voltage to current, power or reverse phase. Types can be magnetically operated, activated on the thermal principle, by induction or by the rotating-disc principle.

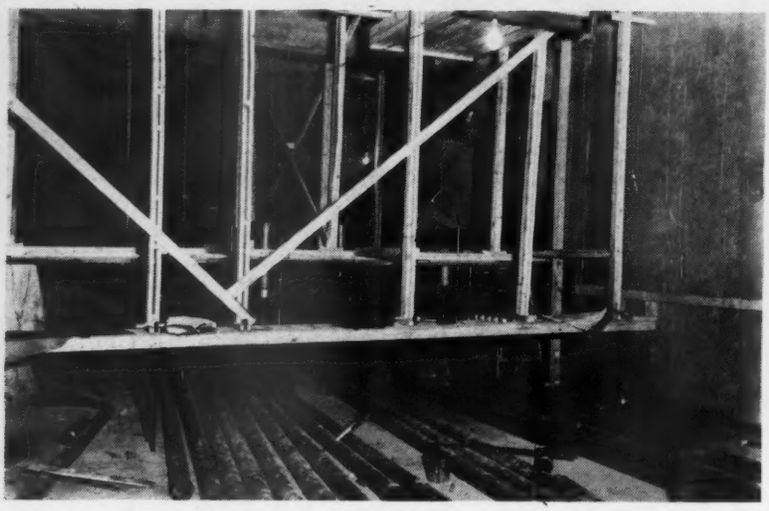
Similar to the relay but designed for greater current carrying capacities is the *contactor* which is made in both shunt and series types and is available with electrical and mechanical locking features. In construction, the contactor is similar to the circuit breaker but it differs in operation since the circuit breaker employs an electro-magnet to automatically open when a fault occurs, while the contactor employs the electromagnet to open or close the circuit under normal conditions. Another difference is that, while contacts of circuit breakers are held in place mechanically, contacts of contactors are held in place by an electromagnet. In using contactors, several advantages are gained, since large currents can be controlled by simple pushbuttons, large manual equipment is eliminated, control equipment can be confined to a single location near the equipment being controlled, automatic operation is possible, and control can be obtained at more than a single point.



WIDE SELECTION in switches is possible, ranging from open knife switches to enclosed and fused safety switches. Small currents can be cleanly interrupted by mercury switches. Disconnecting means include use of hook-sticks, remote control and spring-trip overloading mechanisms, combining multiple levers and fulcrums, resulting in faster, cleaner breaking of arcs.



MONOLITHIC DUCT BENCH of asbestos-cement conduits ready for concrete enclosure.



HEAVY FEEDER CONDUITS to panels in an industrial installation are held in position by wood template and scaffold.

ALUMINUM CONDUIT FEEDERS in trench are tied to pipe stakes and cross pieces awaiting pouring of concrete envelope.

METHODS . . . CONCEALED SYSTEMS

CONCEALED raceway systems are those installed in the ground, in floor and ceiling slabs, in walls and partitions, and in suspended ceilings. Materials commonly used include steel and aluminum conduits, fiber and asbestos-cement ducts, tile ducts and special underfloor raceways. Installation methods applicable to each will be briefly outlined.

Underground Raceways

Non-metallic ducts are commonly used for underground runs because of their non-corrosive and non-electrolytic properties. Fiber ducts and asbestos-cement conduits are extensively used on commercial and industrial jobs. Both are available in conventional wall thickness for use in a concrete envelope and extra heavy walls for direct earth burial. It is more economical to use the heavy wall ducts in systems under four ducts for the fibre type and under six for the asbestos-cement type. Above these limits it is cheaper to buy strength in a concrete casing.

Two duct-encasement methods are generally used. In the built-up or monolithic method, ducts are arranged in a self-supporting structure by use of precast spacers. Concrete is then poured over the entire group. The "tier-by-tier" method is started with a concrete foundation in the trench. The first group of ducts is then laid on it and spaced with a wooden "comb". After concrete has been poured over the ducts and has set, a second "tier" of ducts is laid and encased. A comparatively dry concrete mix is recommended for this latter method. All joints should be made with waterproof compound. In both cases, it is wise to anchor the duct assembly to prevent "floating" and misalignment when the concrete is poured.

Whenever a group of ducts pass under a roadway subject to heavy truck traffic, the concrete envelope should contain a strengthening frame of steel reinforcing rods.

Where a particularly water-tight installation is required, an asbestos-cement water-pipe conduit with rubber ring joints (instead of caulking or compound) is frequently used. This scheme also gives added flexibility to the conduit run.

Steel conduits as well as *aluminum* conduits are frequently installed in the ground, especially where unusually heavy stresses and strains are expected and where conduits are to be pushed under a sidewalk or roadway. When installed below the water table, conduits should be painted with a water-resistant asphalt compound.

When aluminum conduit is used, care must be exercised to see that it comes in contact with no alkaline substance, since alkali will attack the aluminum.

METHODS... CONDUITS IN CONCRETE

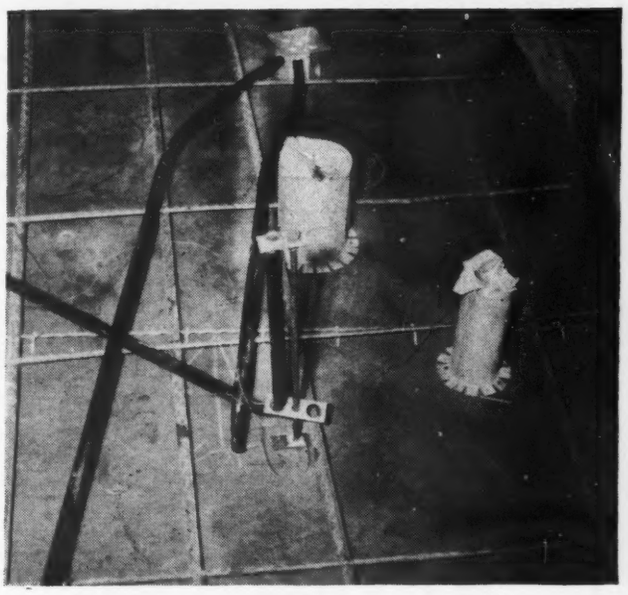
CONDUITS IN FLAT SLAB construction are tied to reinforcing bars; stubbed up outlets are securely anchored to forms.

ELECTRICAL circuits in most commercial buildings are concealed in the walls, floor and ceiling slabs. The present trend in industrial building design is to conceal such conduits as far as is practicable—particularly in the case of lighting circuits. In both cases, considerable field planning precedes actual installation. Close coordination with other trades is necessary in order that the outlets and conduit runs may be spotted and installed before all the re-inforcing steel is laid and the concrete poured. The same is true for installation of inserts for exposed conduit runs.

One of the first jobs of the project superintendent is to *accurately spot sleeves* in the walls or foundations for service conduits. Depending upon the installation technique employed, this may take the form of pipe sleeves, short nipples (when a pull box is to be installed on inside and outside of wall) or conduit elbows for future extension of raceway.

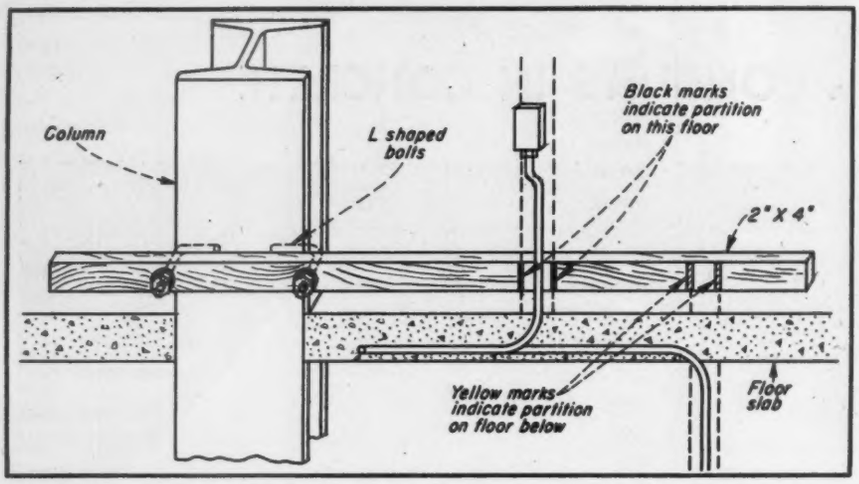
Feeder conduits, because of their size, are rarely embedded in walls or ceiling slabs. They can be installed in the ground under floor slabs where they will not weaken the slab structure. Normally feeder conduits are run exposed on the outer wall, exposed on the basement ceiling, concealed in pipe shafts, in the web of steel columns that are later enclosed, or in concrete columns if their cross-section is great enough to permit. Where feeder risers go through floors, openings or sleeves must be installed before the pour is made.

Where feeder conduits are stubbed up to panelboard or switchboard locations, steel or wood templates are generally installed to keep the conduit stubs securely in place and aligned with future panel knockouts during the concrete pour. Single or double-tier templates may be used, the double-tier ones keeping the conduits better aligned in the vertical plane.

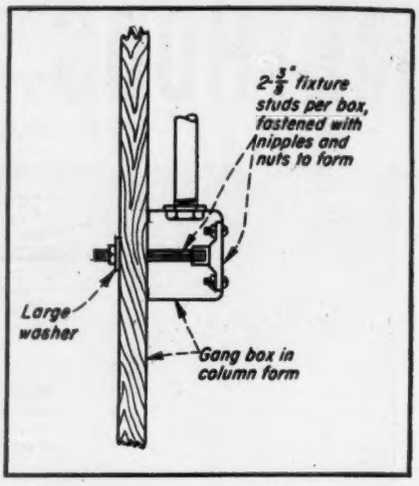


ROD SUPPORT with sliding conduit spacers holds partition stub-ups securely during pour.

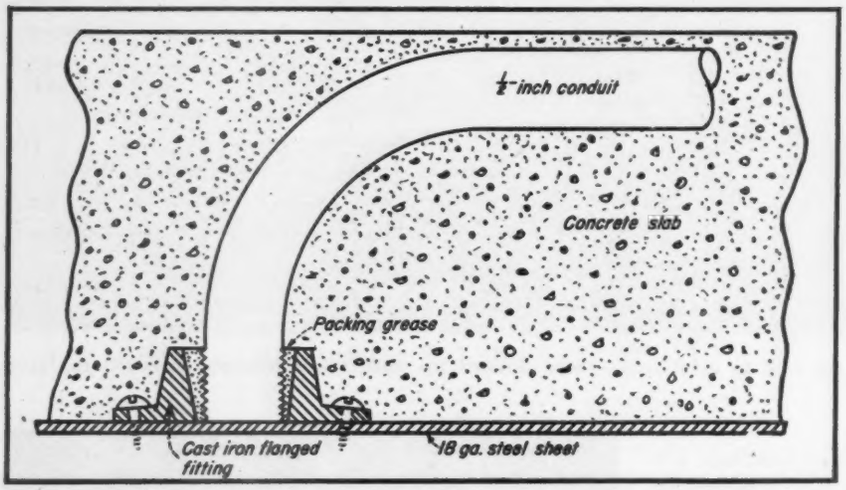
Whether or not sub-feeder conduits are permitted in a floor or ceiling slab depends upon the slab thickness. Normally no conduit larger than 1¼-inch or 1½-inch is permitted.



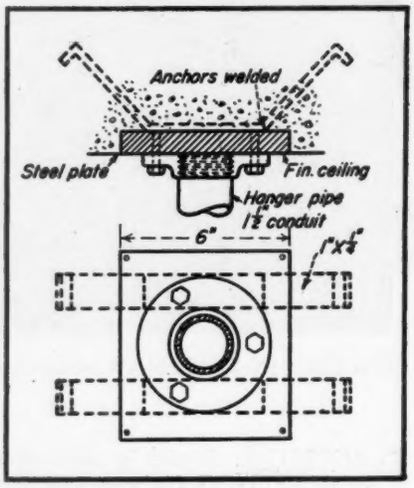
CONVENIENT MARKER spots partition location for conduit stubs during roughing.



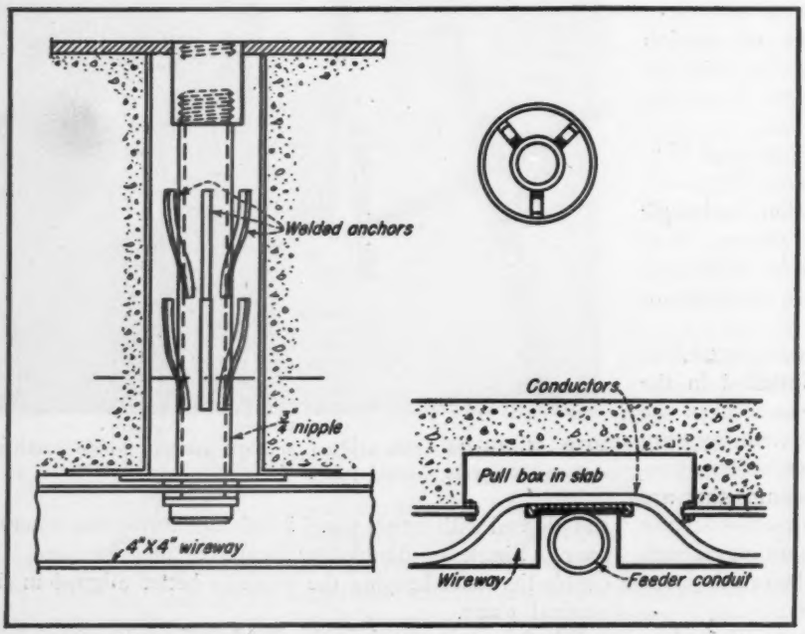
ONE METHOD of anchoring outlets to column forms on concrete construction.



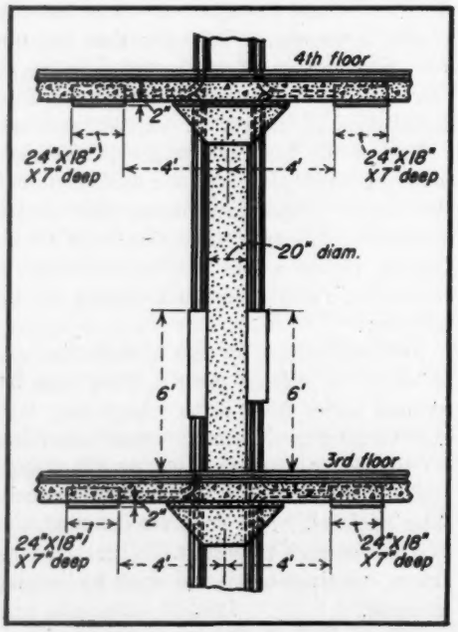
FLANGED FITTING METHOD of installing conduit stubs on steel forms. Packing is with heavy grease.



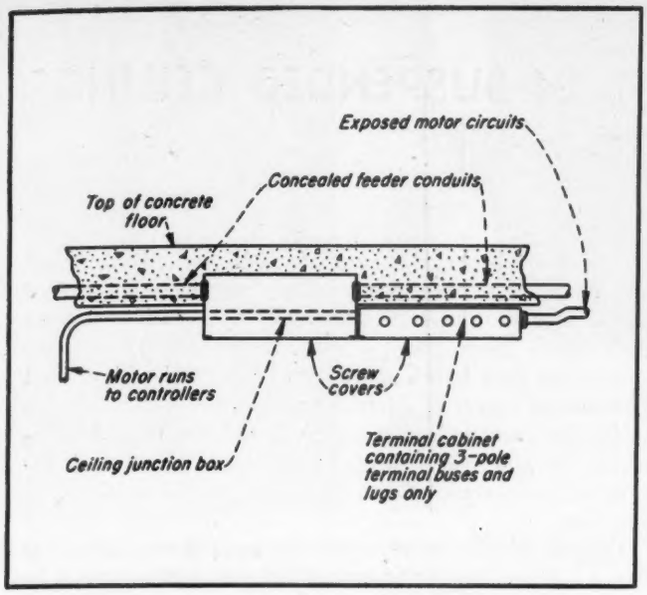
STEEL PLATES with slab anchors support pipe flange.



WIREWAY CONNECTION to floor above is made through slab sleeve and conduit nipple. Anchors hold nipple securely in grout fill. Feeders bypass conduit obstructions through slab pull boxes over wireway.



CONCEALED CIRCUIT conduits leave semi-flush ceiling pull boxes to enter exposed lighting and power panels.


Exposed motor circuits
Concealed feeder conduits
Top of concrete floor
Motor runs to controllers
Screw covers
Ceiling junction box
Terminal cabinet containing 3-pole terminal buses and lugs only

SEMI-CONCEALED junction boxes permit tapping exposed branch circuits to concealed feeders.

Larger sizes must be cast in the beams. In any case the builder should be consulted and a definite decision reached before the work is started.

Branch circuit conduits can generally be installed criss-cross in the slab. Stub-ups to outlet boxes in partitions must be securely anchored to prevent shifting during the pour. One method uses an L-shaped bracket made of small channel iron. The bottom is nailed to the forms, the top bolted to the back of the outlet box which holds the conduit stub. Another scheme uses a long bolt rod welded to a small base plate. The base is nailed to the forms and the rod fastened to the outlet. A steel conduit spacer over the rod has knockouts identical to that of the box and is pushed down over the conduits to hold them securely in place.

All outlet boxes nailed to forms should be stuffed with paper or similar material to prevent obstructions from concrete seepage. Conduit openings should be covered with capped bushings or wood plugs.

Where steel forms are encountered, the problem is more difficult. One method of stubbing down conduit branch circuits involves the use of a floor flange with a tapered bore. The flange is screwed to the steel form flat side down. The conduit is stubbed into the bore. Space between the conduit and flange bore is packed with heavy grease. The flange comes down with the forms leaving a clean opening around the conduit for addition of a coupling and short nipple to the outlet box.

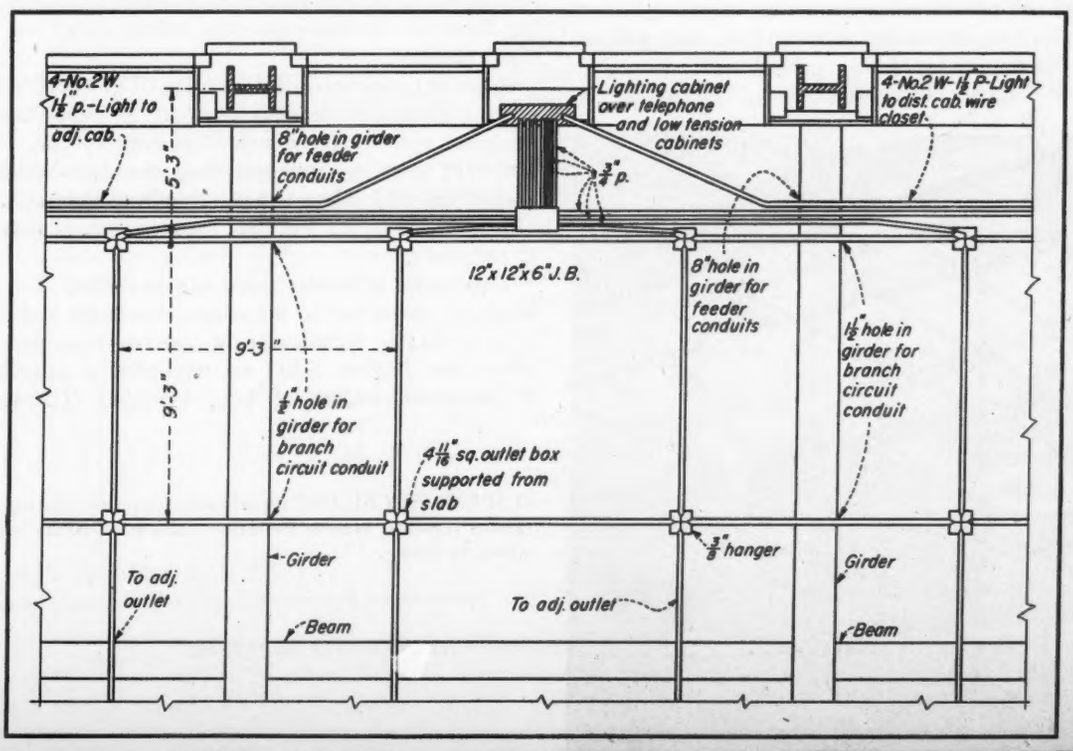
Where outlets for receptacles and switches occur in concrete columns or walls, conduits and boxes must be installed in the forms. Boxes, particularly must be securely anchored to prevent shifting and turning during the pour. Frequently the boxes are fastened to the wood forms with steel banding wire. A more effective method, particularly for gang-boxes, is to equip the box with a fixture stud and bolt. The bolt protrudes through a hole drilled in the form and is securely fastened by a nut which is removed when the forms come down. The bolt and stud are also removed at that time.

Different elevations in floor levels sometimes occur in commercial buildings. To conceal conduits at these points is sometimes quite difficult, particularly where sharp double offsets in conduits may hamper wire pulling. In those cases, offset pull boxes with access covers flush with the ceiling below are generally installed in the concrete slab.

The job superintendent on a concrete or "mud" job has to be on his toes every minute of the time. He must:

1. Accurately spot all openings, sleeves, outlets and inserts when the forms are built and before the pour is made.
2. Have enough men on the job to keep well ahead of the general contracting trades.
3. See that all outlets are securely anchored and all conduit runs securely tied to the re-inforcing steel to prevent floating and misalignment.
4. Keep an electrician on the forms when the pour is being made so conduits that may become misaligned can be promptly straightened.
5. Be alert to last minute changes in outlet or panelboard locations, shifts in partitions, doorways, windows or other decisions that may affect his conduit installation.

GRID SYSTEM NETWORK of lighting branch circuits feeds lighting fixtures mounted in suspended ceiling. Conduits pass through hole drilled in girders.



METHODS...CONDUITS IN SUSPENDED CEILINGS

THE present-day trend toward flush type lighting equipment and concealed air-conditioning and ventilating ducts practically demands a suspended ceiling design. In such construction all piping is installed in the space between the ceiling slab and the suspended ceiling. Conduits and outlets are installed exposed before the steel supporting framework for the ceiling is completely installed.

Generally, heavy feeder conduits are suspended from the slab; branch circuits rest on the ceiling framework. Normally, outlet boxes are installed with flexible conduit connections to the fixtures mounted in the ceiling. In some cases, fixtures will take a direct conduit connection. Care must be exercised that all outlets and fixture housings are securely tied to the ceiling framework.

As in the case of "mud" jobs, electric metallic tubing finds one of its greatest applications in suspended ceiling work. Biggest advantages are its light weight and threadless fittings with the resultant installation economies.

The best method of providing the electrical flexibility demanded by modern commercial, industrial and institutional buildings is to install an underfloor duct system. This provides floor access to lighting, small power, telephone and inter-communication circuits.

Underfloor duct is available in either steel or fiber construction, in rectangular or oval cross-section. Access openings can be had at predetermined spacings (usually 2-foot centers) or can be made after the duct is installed. Whether the installation is a single or multiple-duct type depends upon the number of electrical circuits and systems desired.

Layout may be of the grid type which covers the entire floor area (for center floor outlets); the grouped parallel ducts (for rows of laboratory tables, etc.); or the runaround system which parallels the walls of a building at a predetermined distance. The duct can be installed in monolithic and slab and fill constructions and all their variations.

Each duct manufacturer provides a group of junction boxes, fittings and conduit adapters for his specific product.

Definite rules for installation of underfloor duct systems are contained in Article 354 of the 1947 National Electrical Code. Ducts of half-round or flat top types not over 4 inches wide must have a minimum of $\frac{3}{4}$-inches of concrete or floor above them; flat-top ducts over 4-inches wide or spaced less than $\frac{1}{2}$-inch apart must be covered with at least $1\frac{1}{2}$-inches of concrete. Metal flat-top ducts not over 4-inches wide (for communication circuits) and not over 2-inches wide (for power & lighting) may be laid flush with the concrete if covered with at least $\frac{1}{8}$-inch of substantial floor covering.

Largest conductor permitted in underfloor ducts is a No. 4 and the number of conductors per duct is limited by the 40 percent area rule.

To install underfloor duct, direction lines of cord should first be set at the height of the finished concrete level. Some contractors prefer to use piano wire because it has very little stretch and sag. Junction boxes are then set, leveled, and grouted in (where steel boxes rest on a steel beam they may be spot welded in place). Ducts are then installed between the boxes and all joints made watertight. Duct couplings should also be securely anchored or grouted in place. Panel connections are made with duct fittings or standard conduit.

Before the final fill is poured the entire duct system must be carefully leveled by turning adjusting screws. Marker screws in all fittings must be flush with finished floor level. Many contractors find a transit helpful in leveling extensive duct systems. Again, it is good practice to have electricians present when the actual pour is made.

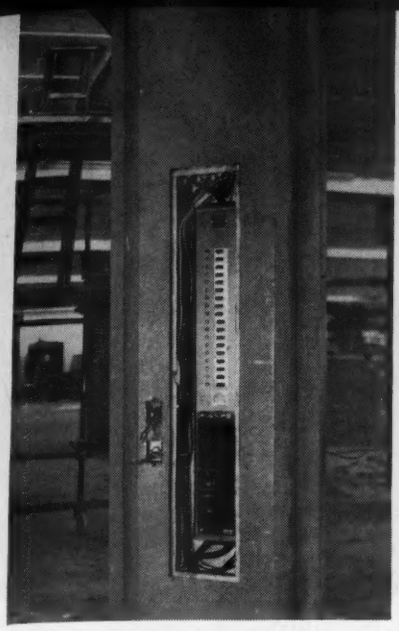
Open-Bottom Raceways must be laid on a smooth pad of concrete at least one-inch thick extending at least one inch on either side of the raceway which must be mechanically anchored to the pad. Where raceway crosses conduits or pipes, fittings to protect the conductors can be used instead of the pad ($\frac{1}{4}$" thickness).

Cellular steel floor is frequently specified by architects for commercial building design. It is a hollow steel interlocking construction that serves as the structural load carrying floor and as raceways (the hollow cells) for the electrical circuits.

A project superintendent on a job of this type is responsible for choosing the cells that are to carry the various electrical systems (telephone, signaling system, lights and outlets); spotting and installing the distribution header ducts from the various panels; installing floor outlets in the cells and identifying the cells (with markers) that are used as raceways.

Two types of header ducts are available. The standard header is insttalled on top of the floor cells and requires a $2\frac{1}{2}$-inch fill; is rectangular in cross-section; has junction units (for feeding cells) on multiples of 6-inches; come in maximum lengths of 4-ft., 6-inches. The top of the

SUSPENDED CEILING framework supports electrical metallic tubing lighting branch circuits. Fixture housings are securely wired to frame.



NARROW TYPE lighting panels are the trend both in commercial and industrial electrical installations.

FLUSH STEEL channel carries lighting feeders from riser duct to flush distribution panel at right.

UNDERFLOOR DUCT junctions are grouted in place first, duct is then installed and leveled to wire guide.

junction unit is used as the screed for pouring the fill. The ceiling header is a surface-type screw-on cover duct for installation on the underside of the cells; is provided with cell-access pilots on 12-inch or 18-inch centers; comes in 4-foot and 4-ft., 6-inch lengths.

Header ducts are installed at right angles to the cells; are connected by vertical elbows and duct extensions to panels mounted parallel to the cells; and by cell ells and conduit to panels at right angles to the cells.

Where header ducts feed specific cells, a hole is cut between the duct and cell by a circular hole saw. A grommet bushing is then inserted to protect conductors.

Each electrical system requires a separate header duct. This permits access only with calls of that particular system. To minimize wire pulling, headers per system should be spaced not more than 100 feet apart. Generally, cells and headers are used only for branch circuits. Feeders and sub-feeders to panels and other centers serving headers, are run in separate conduit or other raceways.

Conduit fittings and conduit can be used from the cells to column, wall or partition outlets. Markers identifying particular cells of each system are installed on top of selected cells and finished flush at the screed line. At least one marker per system for every 200 square feet and not less than two per system per room are recommended. Similar markers should be placed on every sixth concealed junction unit.

Where the underside of cellular steel floor remains exposed (as in industrial plants, warehouses, etc.) lighting fixtures can be mounted directly to the cells. One contractor cut access holes in the duct and welded on two threaded studs that supported conventional swivel cover fixture hangers. Outlet boxes were eliminated. Fixture splices were pushed up into the cell containing the branch circuit conductors.

Allowable Number of Wires in Standard Header Duct
(General Electric)

Size AWG.	*No. of wires in 40 percent of Header Duct Area* Types R, RH, RW	Types T, TW, RU
14	109	185
12	90	145
10	54	112
8	33	61
6	20	31
4	16	23
3	14	20
2	12	17
1	9	12
0*	8	11

*(largest conductor permitted by N.E.C.)

Panels and Outlets

Flush installation of distribution panels, pull boxes, outlets and other equipment enclosures in walls, partitions and columns requires rigid mounting before the bricklayer or carpenter closes in. Unlike concrete work, there are no forms on which to anchor the equipment. A supporting frame of some type must be made.

Generally, angle-iron or channel-iron (for heavier tubs) uprights are installed on the steel frame of the building. Bolting, spot-welding or clamping methods may be used. Some contractors find the flexible mounting features of Unistrut channel (no drilling necessary) proves more economical. Panels are then fastened to the uprights and conduits installed so all is firmly in place when the wall or partition is constructed.

Methods previously outlined are used for small outlets. Where they are spotted at steel columns, a perforated steel band around the column with a pipe nipple spacer, or a spacer welded to the column works well. Practically any type of a support can be used—if it is rigid.

In all cases, care must be exercised that boxes will be flush with the finish surface and that they are not knocked out of line by other trades. Again, the job superintendent must be alert to last minute changes that might affect his panel or outlet locations. Close cooperation between all trades is a must in this type of construction. It is also in the interest of accuracy to be present when finishing of walls and partitions is effected so that any local conditions altering the electric installation plan can be noted and corrected immediately.

PULL BOX ELIMINATES awkward offset and direction change in exposed conduit run.

SPECIAL THREE-WAY PULL BOX with cable supports takes care of elevation and direction change.

METHODS... EXPOSED RACEWAYS

IN general, the project superintendent is under less pressure from other trades when he installs an exposed raceway system than he would be if it were a "mud" job. His immediate concern is to see that sleeves and openings of sufficient size are provided where conduits and ducts must pass through walls, floors and ceilings; also that preset inserts are installed where necessary to support his circuits. After the building shell is completed, he can proceed at a greater pace.

Types of Raceways

Choice of raceway is normally made by the engineer who designs the electrical distribution system. Installation is the responsibility of the project superintendent. In general use are conduit raceways (rigid, thin-wall, flexible), wireways and cable troughs, and various types of bus duct (enclosed bus bar assemblies). In some cases armored cable, non-metallic sheathed cable, and open wiring may be recommended.

Most commonly used raceway for general distribution use is conduit with its array of fittings that permits installation under practically all conditions and for all purposes.

Rigid Conduit is used in all cases where systems must be protected against mechanical injury and in all hazardous locations.

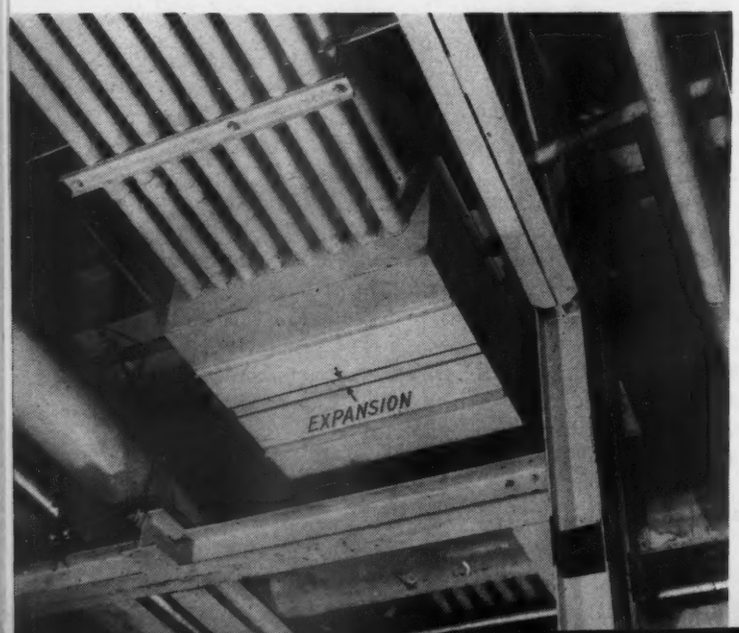
Electrical Metallic Tubing finds extensive application where there is less danger of mechanical injury, but a protected system is desired. It has essentially the same range of fittings as the heavier rigid conduit.

Flexible Metal Conduit (Metallic tubing) is used with all raceways where flexible connections to machines and equipment are necessary.

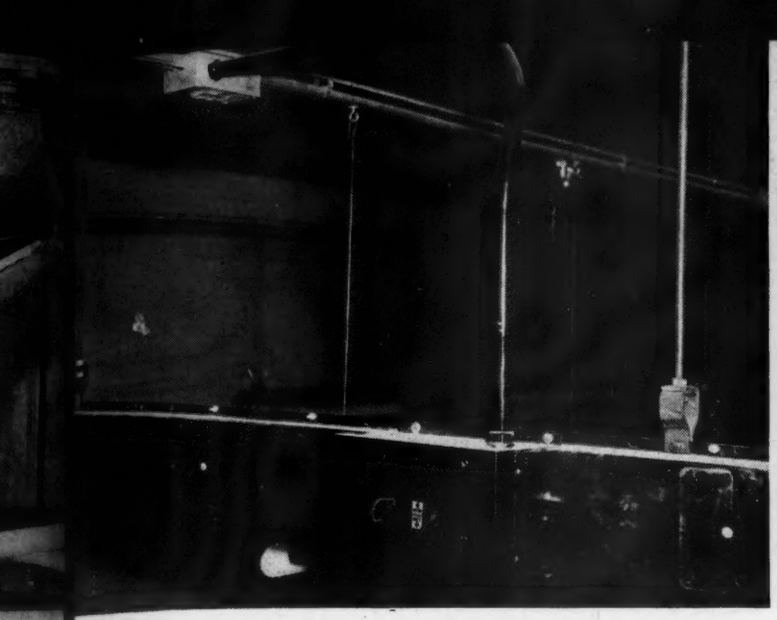
Wireways and Cable Troughs provide convenient raceways for large numbers of conductors feeding branch circuit raceways. The conventional wireway is a rectangular (or square) metal trough with a hinged cover and knockouts on three sides; can be bolted together to form a continuous raceway; has numerous fittings for making turns and offsets. For larger conductors (above 500 MCM) special troughs are frequently used.

Bus Duct is generally used where unusual operating flexibility is desired. Its biggest application is in industrial plants where frequent relocation of machinery and revamping of production lines may occur. It is a system of metal enclosed bus bars with access openings at regular intervals. When a machine is relocated, only the motor tap-off unit need be disconnected from the duct and reconnected at the new location. Frequently heavy feeder ducts (without access openings) serve the branch circuit distribution ducts.

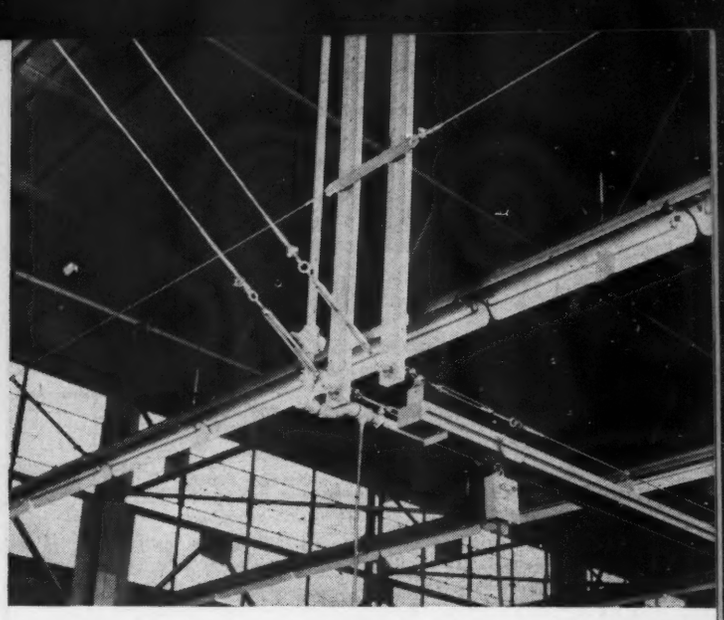
Trolley Duct—an adaptation of bus duct that provides continuous access to the buses—is frequently used for lighting and power tool circuits. Movable contacts (trolleys) connect fixtures or tools to the circuits. Such flexibility permits movement of tools and quick change of lighting layout patterns.



EXPANSION FACILITIES in a long run of 2 by 16 heavy conduits are provided by a telescoping split pull box.



MESSENGER-SUSPENDED trolley duct for lighting is fed from a 3-phase 4-wire power distribution duct.



DEAD-END BRACKET for messenger cables supporting power trolley duct and air lines in an industrial plant.

Armored Cable—more commonly known as BX—is frequently used as circuit extensions in walls and partitions (particularly where it must be fished in). Non-metallic sheathed cable finds similar applications where local ordinances permit.

Routing of Feeder Raceways

Where should a raceway or group of raceways be installed? Although the system designer may have indicated a preference, final routing cannot be decided until actual job conditions are known. That, again, is the responsibility of the job superintendent.

Pipe Shafts are usually designed in multi-story buildings where piping for various systems serves each floor. These are particularly advantageous in radial distribution systems with large numbers of feeder conduits. Distribution or tap-off cabinets are mounted at each floor level as well as cable support boxes at specific floor intervals. Conduit support brackets are installed at each floor level. A pull-box and conduit riser diagram showing actual location of feeder conduits and cables is helpful for both conduit and cable installation.

Aluminum conduit, because of its light weight (about one-third that of steel) and non-magnetic properties, affords an ideal raceway for long vertical risers. Multiple conductors of a single phase can be carried in a single conduit and cumbersome cable crossovers at terminal points eliminated.

Where excessively heavy feeder capacities are encountered, vertical bus duct is frequently used either in pipe shafts or exposed. Installation problems are simplified since a single duct may have the capacity of several parallel conduit feeders. Tap-off breakers can be easily and quickly installed to feed floor distribution panels.

One point to remember when installing new vertical feeders in existing buildings. *Always check the structural steel design to be certain it will carry the combined load of the new feeder circuits.* Frequently re-inforcing steel must be added.

Horizontal Feeders can be installed in numerous ways. Building structural features generally dictate installation methods. Frequency of direction change and panel location are other dominant factors.

Multiple conduit feeders are generally grouped in tiers and suspended by trapeze hangers. Parallel mounting in a single horizontal or vertical plane also is frequently used. Roof truss design should always be checked. Conduits can often be laid on the bottom chord and secured by V- or J-bolts—a method that keeps feeders out of the way and simplifies installation.

Horizontal bus duct and wireway feeders can be installed in a similar manner. The main difference is that fewer runs are involved.

Heavy armored cable feeders are most easily installed in a supporting trough. Where run opens particular attention must be directed to adequate supporting means.

Branch circuit layouts and the specific type of system installed is dictated by outlet location and degree of flexibility required. Branch conduits are usually grouped from the distribution panel to points where they branch off to feed the outlets. Where large numbers of conductors are involved, wireways are frequently used with outlet conduit runs. Whether circuits are installed in roof trusses, on walls or in floor trenches depends upon the equipment layout and location. The shortest distance from panel to outlet, while still conforming to building lines, is the best rule to follow.

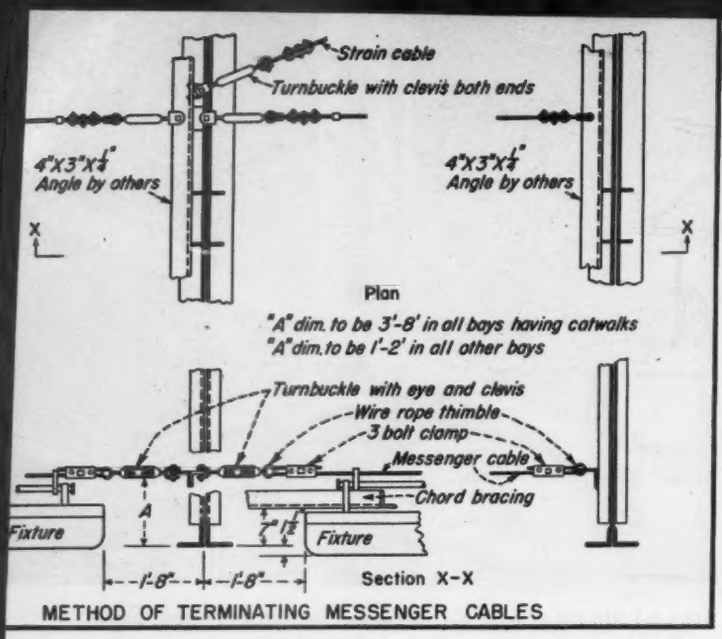
Modern practice is to use distribution type bus duct for power branch circuits particularly when overhead distribution is required. Advantages include: Installation ease, tap-off flexibility, large current capacity, and reuse features. Connections from duct to machine can be made with conduit or flexible cable drops.

For lighting branch circuits, continuous runs of trolley duct offer extreme flexibility of fixture location and light intensity (close grouping of units). Installation is simplified when this is combined with a 3-phase, 4-wire 110/220-volt power distribution duct. Lighting circuits are tapped off the duct, eliminating distribution centers. Group or individual fixture control of lighting units can be used.

Bus duct installations are usually tailor-made from the standpoint of accurate field dimensions for length of runs.

Pull Boxes and Troughs

Many contractors feel that an installation can never have too many pull boxes, particularly during cable pulling operations. Long runs of grouped conduits require pull boxes at predetermined intervals to facilitate cable installation—particularly if ells and offsets are already in the run. Frequently pull boxes solve awkward offset problems at wall



METHOD OF TERMINATING MESSENGER CABLES

DETAILS OF COLUMN dead-ends for messenger cable runs.

lines or changes of elevation. They can be used to advantage for conduit terminals over switchboards (long troughs); at all conduit junctures; and where splices in long cable runs are required.

Although the National Electrical Code has definite rules as to minimum size (Section 3708), most contractors use larger boxes. Many a back-breaking man-hour has been saved by a farsighted job superintendent who provided extra space in pull boxes.

Boxes equipped with removable cable racks assure adequate support and alignment of cables in multi-tier conduit runs and over switchboards where conduits enter the end of a long trough.

Expansion Joints

Expansion joints are required in all conduit runs where they cross the expansion joint of the building. They may be required at more frequent intervals where conduits are exposed to radical temperature changes.

In concealed installations, the conduit, or conduits, can be stubbed down on each side of the structural expansion joint into outlet or pull boxes. If outlet boxes are used, they are bridged by a conduit section, one end of which telescopes into the outlet. When pull boxes are used they are usually of the split type that telescope into each other. Flexible bonding jumpers should be used to maintain a continuous ground on the conduit system. For single conduits, a loop of flexible conduit or BX is sometimes used between boxes.

For exposed multiple conduit groups a large telescopic pull box can be installed. For single conduit lines, a conduit sleeve over the ends of the circuit conduit is sometimes used. Bonding jumpers should be attached to maintain a continuous ground on the conduit line.

Supporting Methods

Three conventional methods of supporting exposed raceways are by straps, hangers and messenger cable. Any one or a combination of the three can be found on most installations. Actual mounting techniques will differ according to building construction and architect's or engineer's restrictions.

On concrete construction, either pre-set inserts or expansion shields are used. Latest development in this field is a threaded insert that is fired into the concrete or brick with a blank cartridge gun-type tool. High speed electric and air operated drills and hammers are available for drilling concrete for expansion shield installation.

On steel construction, beams, columns and trusses are either drilled or punched for mounting bolts. Where this is prohibited, beam clamps or spot welded studs or mounting pads can be used.

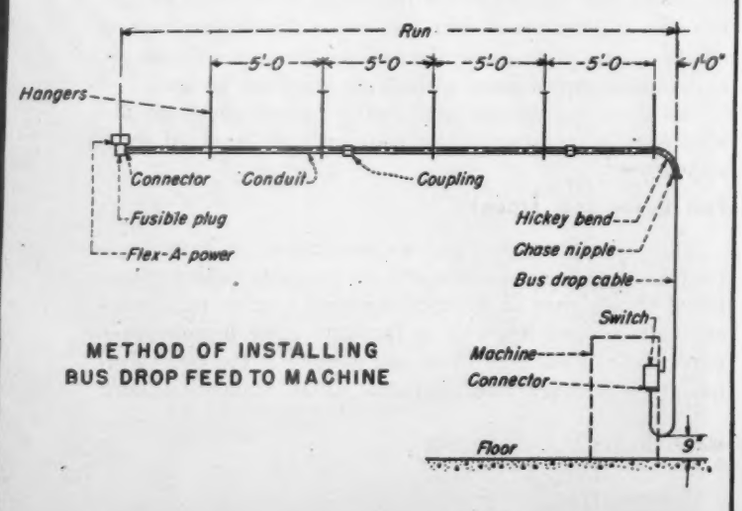
The conventional nail, wood screw and lag screw or bolt is commonly used on wood construction.

Conduit Straps are normally used on single conduit runs and parallel groups spaced far enough apart to permit strap installation and mounted direct to walls, ceilings or columns.

Conduit Hangers are generally used where suspension supports are necessary, as in high bay and monitor areas. Hangers may be of the single rod or double rod trapeze type depending upon size and number of conduits to be suspended. Trapeze hangers for multi-tier conduits are normally fabricated of channel or angle iron with "rungs" between tiers. Frequently the structural strength and mounting flexibility of Unistrut channel dictates its application to hanger design. Similar hangers can also be used to support bus duct, troughs and wireways. As in the case of conduit, various types of mounting brackets can be made for wall mounting.

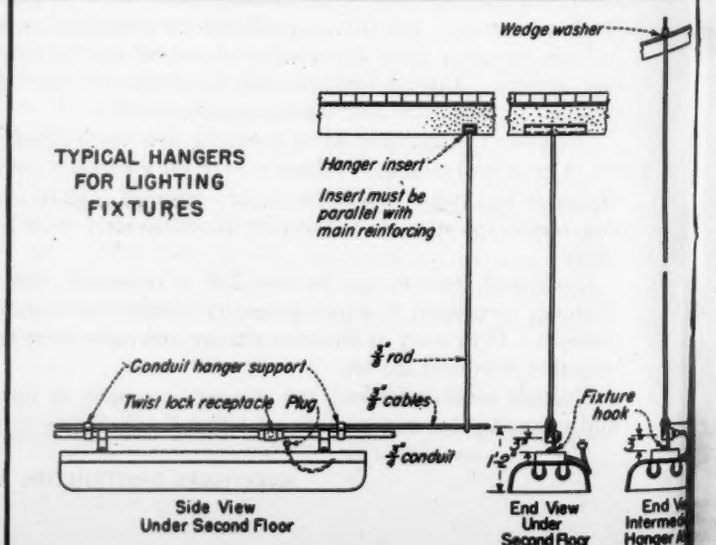
Messenger Cable Suspension of circuit conduit and light-

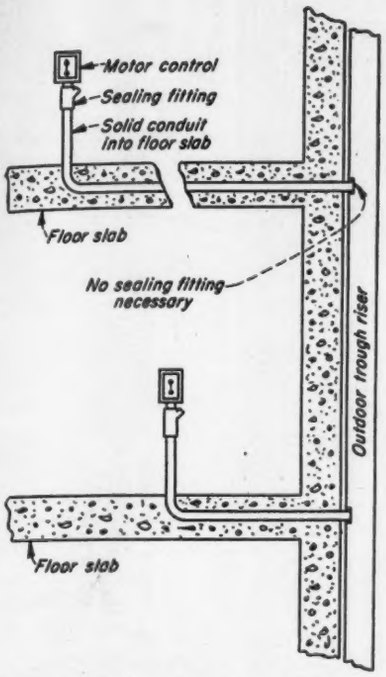
DETAILS of machine connections using conduit and bus drop.



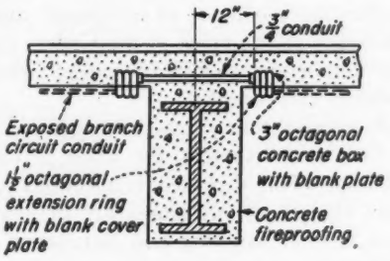
METHOD OF INSTALLING BUS DROP FEED TO MACHINE

TYPICAL ROD supports for messenger cables.

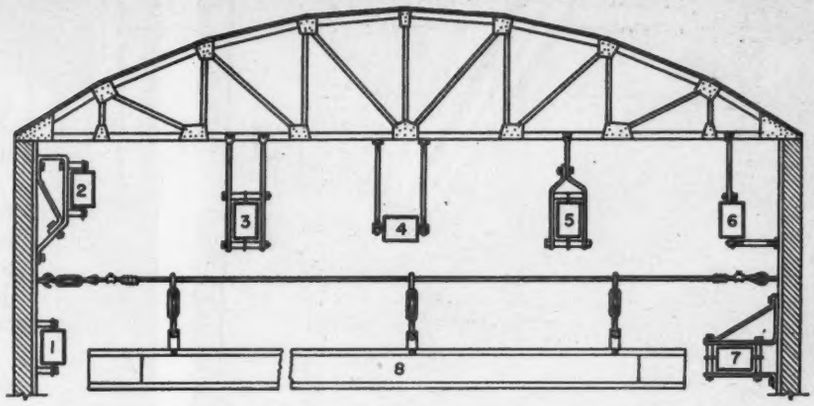




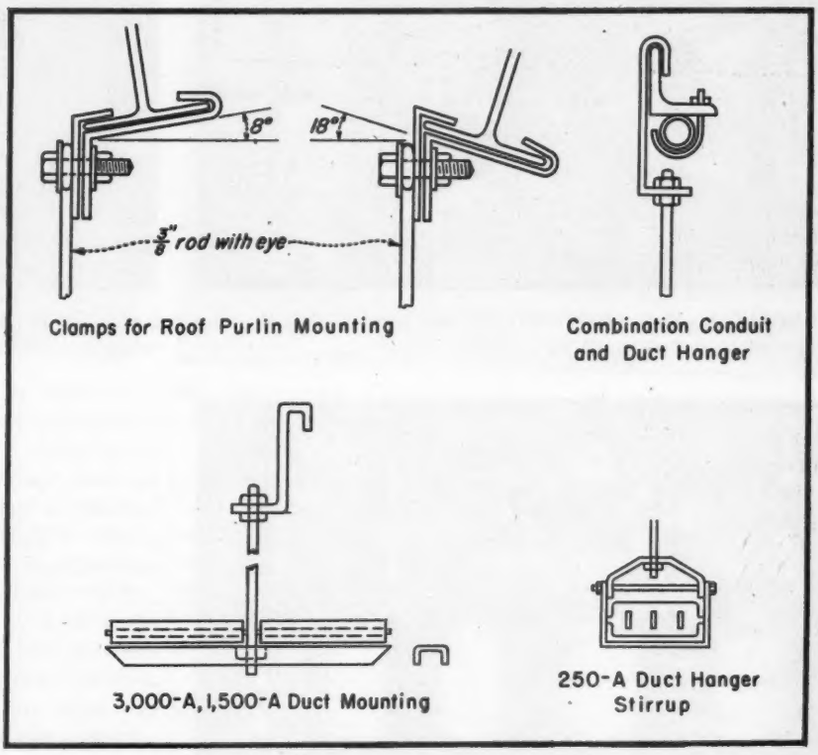
OUTDOOR TROUGH riser feeds explosion-proof equipment in building. Continuous conduit in branch (no couplings) requires only one sealing fitting.


12"
¾" conduit
Exposed branch circuit conduit
½" octagonal extension ring with blank cover plate
3" octagonal concrete box with blank plate
Concrete fireproofing

CONDUIT JUMPER in slab offsets beam in exposed conduit run.



EIGHT typical methods of supporting bus duct.



TYPICAL SUPPORTS for power duct installations.

ing fixtures made its debut in the electrical construction industry with the advent of the long fluorescent fixture that normally requires dual supports. It found extensive application on projects where lines of fixtures were spotted parallel to and between roof trusses in industrial plants; also in high bay and monitor areas. Now its application has expanded to the point where it is used wherever difficult mounting and suspension problems are encountered on power bus duct and other raceways as well as lighting circuits.

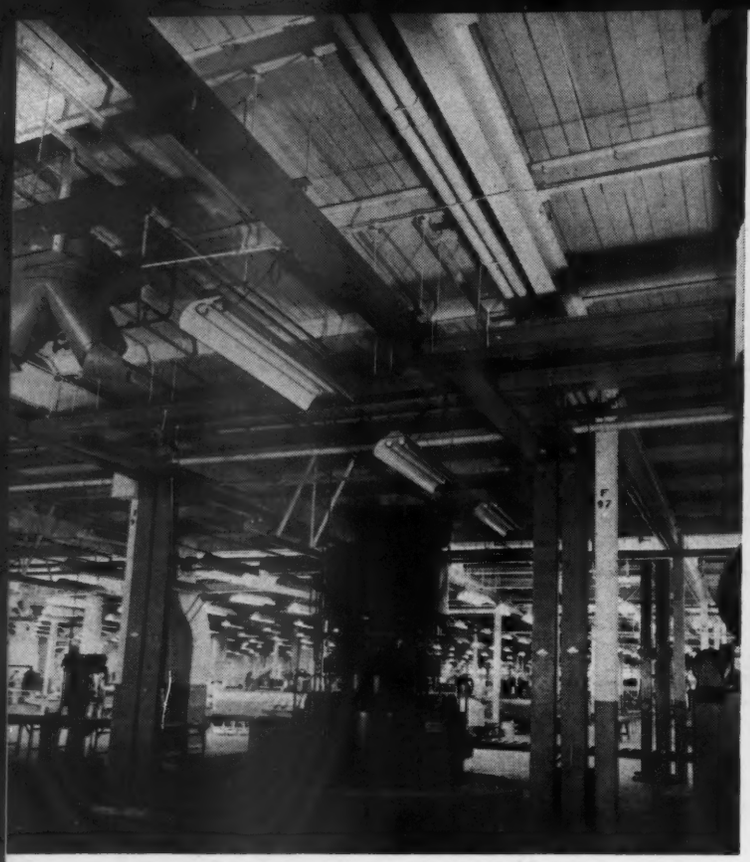
Intermediate supports are made in the usual manner with bolt rod. Any sag that might occur in the messenger cable is taken up by turn-buckles at the dead-end points. Dead-end design for long span messenger cable runs is an important factor of successful installation. Wherever possible dead-end brackets should be mounted to heavy steel structural members. In some cases re-inforcing plates must be added.

Where there is danger of buckling beams, dead-end bridles can be fashioned from messenger cable, turnbuckles and aligning plates. Ends of the bridle are fastened at the junction of roof trusses and beams. Long span messenger cables are fastened to the aligning plates in the bridle. This scheme reduces bending moments on the supporting beams and resolves stresses into compression components at roof truss junctions. In any case, the structural steel designer should be consulted before messenger cable dead-ends are fabricated and installed.

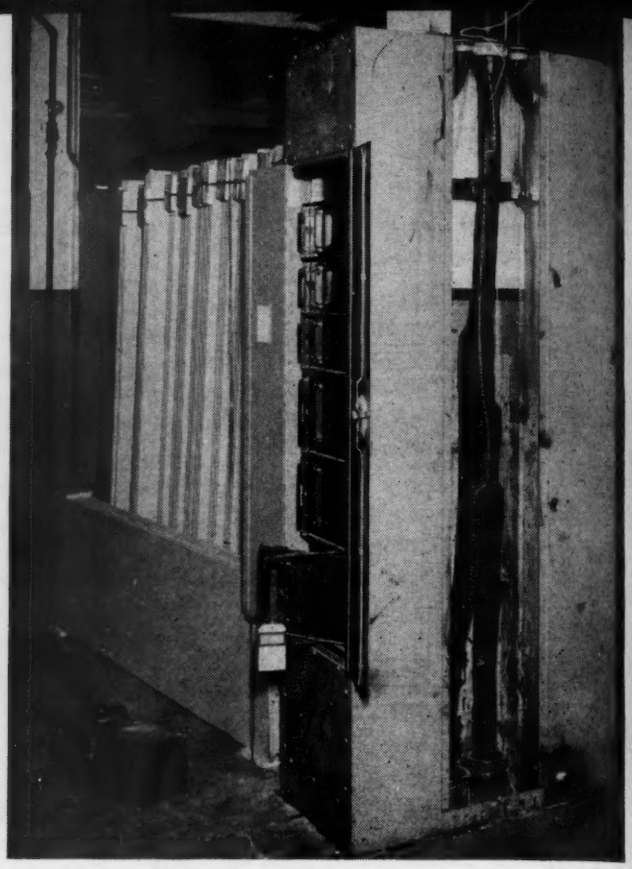
Manufacturers of distribution equipment offer a complete line of mounting accessories for messenger cable installation of their specific products.

Rigid Frame Suspension is sometimes preferred to messenger cable systems. Angle iron, channel iron or Unitstrut channel may be used. The general idea is to reduce the number of supports on long spans while still retaining a rigid mounting of equipment.

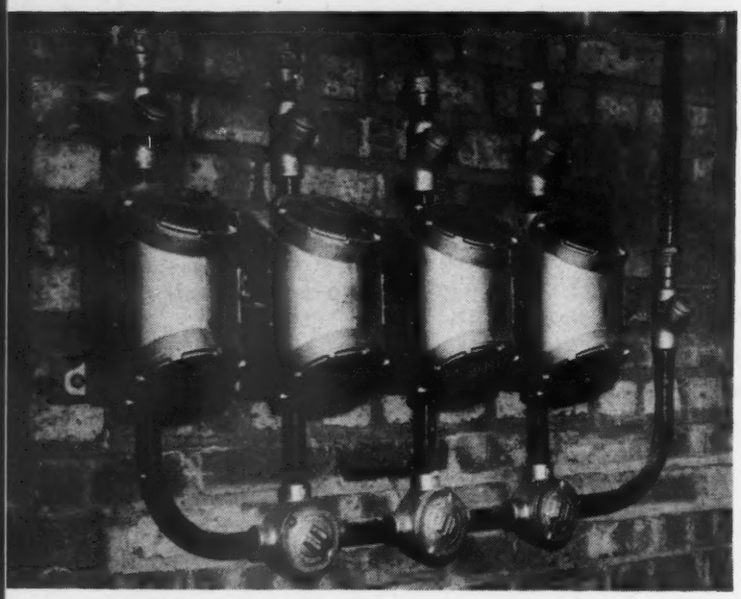
Cutting Beam and Girder Webs is sometimes permitted to eliminate awkward offsets of larger conduits. Special permission of the structural designer is required. Frequently, web re-inforcing plates must be added if the conduit run occurs where excessive stresses are on the steel structure.



VERTICAL AND HORIZONTAL installation of feeder bus duct in an industrial plant.



BACK-TO-BACK PANELS and steel column web form cable splice box. Screw cover encloses splice.



CIRCUIT CONDUITS leading to and from these explosion-proof circuit breakers must be equipped with sealing fitting.

Panels and Cabinets can be mounted to free-standing racks, wall-mounted racks or directly to the walls or steel columns. Present trend on both industrial and commercial construction is to use long, narrow panels that can be mounted in the web of steel columns or concealed in built-up columns. Bolts, brackets, clamps or welding can be employed depending upon owner's restrictions as to technique used.

Wiring for Hazardous Locations

Article 500 of the National Electrical Code defines three distinct Classes and nine categories where hazardous explosive gases, liquids, dust and fibers may exist. Electrical installations in these areas must be of a specialized type using fittings, enclosures and equipment especially designed for these specific applications. Choice of equipment must be made in strict adherence to the rules of the Code. Approval of local Code authorities should be sought before such equipment is ordered and installed.

Rigid metal conduit is the raceway generally required in all of these areas. In a few instances, the Code permits electrical metallic tubing. Full threaded connections are the rule. Outlets and equipment enclosures are of heavy cast metal and require careful handling and installation to prevent cracking. Their construction is designed to prevent possible arcs from reaching the surrounding hazardous atmospheres.

Wherever conduits enter or leave an explosive area, or a motor or switch control unit in such areas, special sealing fittings must be inserted in the conduit line. After the conductors are installed, these fittings are filled with a special sealing compound. Considerable economies in hazardous area installations can be effected by installing major control equipment in a non-hazardous location (on the outside wall of the building or room). One example is the installation of a weatherproof distribution panel on the outer building wall and installing branch circuit conductors in an exterior riser trough. Conduit connections to motor control units were installed in the concrete slab and required a sealing fitting only at the motor control unit. No couplings were in the slab conduits.

Particular care must be exercised that all covers to fittings, circuit control equipment and other devices are securely fastened and that gaskets are installed where required on vapor-proof installations.

Rigid supporting methods are required for such conduit installations to eliminate possibility of any strain on the threaded connections. Where flexible connections are necessary, special explosion-proof flexible conduit is available.

METHODS... CABLE INSTALLATION

VERTICAL RISER CABLES must be supported at regular intervals to remove weight strain. This cable support box is typical.

RECOMMENDED CABLE PULLING lubricants should be used to reduce strain on cables during pulling operations.

HEAVY cables provide the toughtest installation problems. For vertical raceways, cables should be fed in from the top of the run so the weight of the cable will help pull itself into the raceway. Reel set-up is simplified if multiple conductors are cut to length and wound on a single reel at the cable plant. To reduce undue strain from cable weight, cable support boxes are installed in long vertical risers. Maximum spacing according to Section 3014 of the 1947 N.E.C. is as follows:

Cable Size	Maximum Spacing of Supports in Feet
18 to 1/0	100
2/0 to 4/0	80
250 to 350MCM	60
350 to 500 MCM	50
500 to 750 MCM	40
750 MCM and larger	45

Many contractors reduce this maximum spacing in actual installation practice. Split, wedge-type cable support blocks are installed around the conductors in the conduits at the support boxes.

For horizontal feeders, cable weight is a definite obstacle and more effort must be used at the pulling end. Care must be exercised that cable insulation is not "rubbed" when it is fed into the pull box. Lubricants recommended by cable manufacturers should be used to facilitate cable pulling. One unusual discovery is that a damp cloth provides the best lubricant for neoprene jacketed cables.

Just where the reel set-up must be made and the pulling equipment stationed, is a matter for the job superintendent to decide. Normally he makes this decision at the time the conduit layout is planned, spots his pull boxes accordingly and makes provisions for anchoring his pulling apparatus.

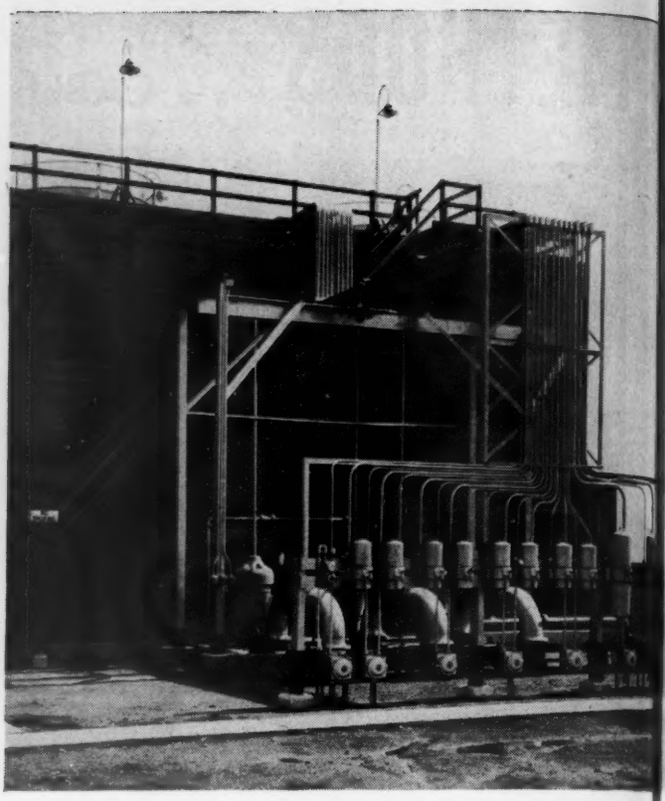
Installation of branch circuit cables is much less of a chore. Normally, they can be pulled in by hand with an ordinary fish tape. Pulls are shorter since they are made from outlet to outlet. Cables are smaller and lighter in weight than feeder conductors. Many contractors use portable reel stands that accommodate from four to eight coils of branch circuit wire of different colors. These can be pulled from area to area, or room to room during cable installation.

Special Tools

Every contractor is alert to new developments in power and hand tools that will reduce installation time and increase the efficiency of his shop and field operations. Available for heavy construction work are hydraulic conduit benders, pipe pushers, jacks for raising and jockeying heavy equipment into position. Electric power driven tools are a must on the large construction project. Pipe cutting and threading machines, cable pulling winches, hand or power operated cable pullers that clamp on the conduits, power band and hack saws and spot welding units are in the tool inventory of all large contractors.

Hole boring machines are used to cut openings in concrete slabs; new attachments are increasing the flexibility of the electric drill; power actuated insert tools speed installation of exposed work; special tools are available for cutting openings in underfloor duct and cellular steel floors. Hydraulic and hand tools for crimping wire and cable lugs are on the market. Portable electric drill stands are a common sight on construction projects. Both the contractor and his mechanics desire tools that will make their job easier to accomplish.

Top idea man for new tools and their possible application is the job superintendent and his field crew. He is the one the contractor and the manufacturer turns to when a new device is developed or even in the embryo stage.



SPECIAL LOCATIONS require special wiring practices. Typical are such areas as those shown. Left, spray booth illuminated through glass panels in area rated as hazardous. Right, typical Class 2 area employing full hazardous area wiring and motor controls.

METHODS... SPECIAL LOCATIONS

Hazardous Area Wiring

Wiring in hazardous locations requires specialized materials and installation methods. The work is covered under a separate section of the Code, Article 500. Requirements differ for different types of explosion or fire hazards.

Class 1 locations are those containing gases of a combustible type. They are further subdivided on the basis of whether flammable mixtures of gas and air are present continuously or only occasionally.

Generally, the equipment installed and the methods employed must be of a type that will prevent gases ignited inside the wiring system from igniting the surrounding atmosphere. Such systems are not vapor tight in the sense that equipment is not specifically designed to prevent any possible entrance of gas into the wiring systems. In such locations it is impractical to install a gas tight system that can be depended upon to stay gas tight through ordinary use and maintenance. Explosion-proof wiring means wiring and equipment enclosed in a case which is capable of withstanding an explosion of a specified gas or vapor which may occur within it, and preventing the ignition of the specified gas or vapor surrounding the enclosure by sparks, flashes or explosions of the gas within.

The design of enclosures for equipment is carefully worked out to meet these requirements, but understanding of the principles involved and careful installation are just as important at the job level.

Explosive pressures depend upon the type of gas involved and the amount that can be set off. This is the reason for breaking up the explosion proof job into relatively small chambers by seals and sealing fittings.

Rigid conduit is required since the raceway may become filled with an explosive mixture. Further, threaded joints are flame tight.

Conduit systems must be installed with the following considerations in mind:

1) limit the volume (through frequent seals)
2) prevent pressure piling (as flame travels it compresses the gas before it and increases the force of the explosion)
3) prevent travel of explosions to other parts of the system.
4) prevent travel of explosive mixtures to non-explosion proof equipment and non-hazardous areas.

These are accomplished by proper installation and care of seals and sealing fittings.

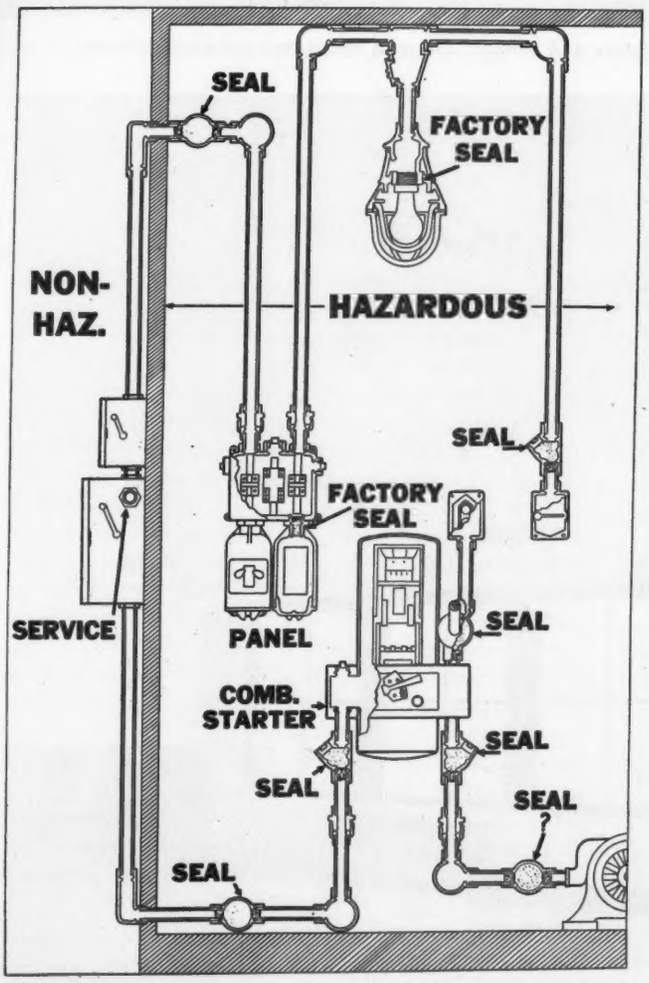
Seals are installed at all arcing devices such as switches and controllers, where conduits lead from hazardous to more hazardous areas and at terminal boxes on 2 inch conduit and larger. Good practice requires that long runs be sectional-

ized to reduce the volume of gas available in any section of the system.

Unusual care must be employed in the conduit work. Conduits and nipples must be set up tight with at least 5 threads engaged. All fittings must be approved for the class of hazard present and designed to operate at safe temperatures. Besides great strength the fitting must have all joints and assemblies designed to restrict the flow of gas through a comparatively long path in its escape to the outside. Screw threads and machine surfaces are used. Flat joints must be made with great accuracy. When such fittings are received on the job they should be stored well away from dirt and damage. Covers should remain on until installation and then carefully lined up in the original position. Although explosion-proof equipment is large, bulky and rugged it should be handled and protected carefully.

Explosion-proof wiring systems are no stronger than their weakest points. Rigid adherence to letter and spirit of the Code, realistic appraisal of the hazard area and careful, skilled installation are essential.

Division 2 hazardous areas are those where explosive gasses are not always present. Requirements are somewhat less stringent but it is sound engineering to err on the cautious side. When conditions are "right" the hazards are fully as serious as though explosive gases were always present.



PICTORIAL DIAGRAM of typical hazardous area wiring methods and facilities for sealing conduits between devices and extensions to non-hazardous areas.

Class II locations involve combustible dusts. They may be grain dusts or powdered metal. Many ordinary materials in finely divided form will explode with varying degrees of violence. Class II wiring systems must provide dust tight enclosures (practical in that the material must be suspended in air to be explosive. In the case of gases they are an inseparable part of air). It must operate well below the ignition temperature of the dust and must bar the entrance of conducting dust. Generally heat is the most important design problem. Dust can blanket the equipment, prevent heat dissipation and thus cause a dangerous rise

Wiring methods require rigid conduit with threaded joints. Switches, circuit breakers, fuses, panelboard cabinets, lighting fixtures and motors must be dust tight. Equipment which generates heat such as motors and lighting fixtures must be approved for the class of hazard and built to operate at not more than 165 degrees C when covered with a dust blanket. Gaskets must be vermin proof.

Junction boxes and fittings need not be dust tight unless the dust is electrically conductive. Control equipment must be in dust tight enclosures.

Division 2 locations are somewhat less hazardous and the requirements are less stringent. Electrical metallic tubing is permitted. Fittings and boxes must prevent the escape of flames or sparks.

Class III hazards are those from flash fires in combustible fibers and flyings. Wiring methods required are rigid conduit, boxes and fittings designed to prevent the escape of sparks or burning materials, dust tight enclosures on switches and circuit breakers and lighting fixtures with lamps in a dust tight enclosure.

In selecting equipment for hazardous areas it is important to thoroughly check the class of hazard against the equipment listing. Equipment for Class I hazards is not necessarily rated for Class II. If listed for both it will be so marked.

Wiring in Existing Buildings

Rewiring of existing buildings is one of the major markets of electrical construction. On alteration jobs involving building work the methods and techniques are substantially similar to new construction, however the preliminary planning is critically affected by structural features.

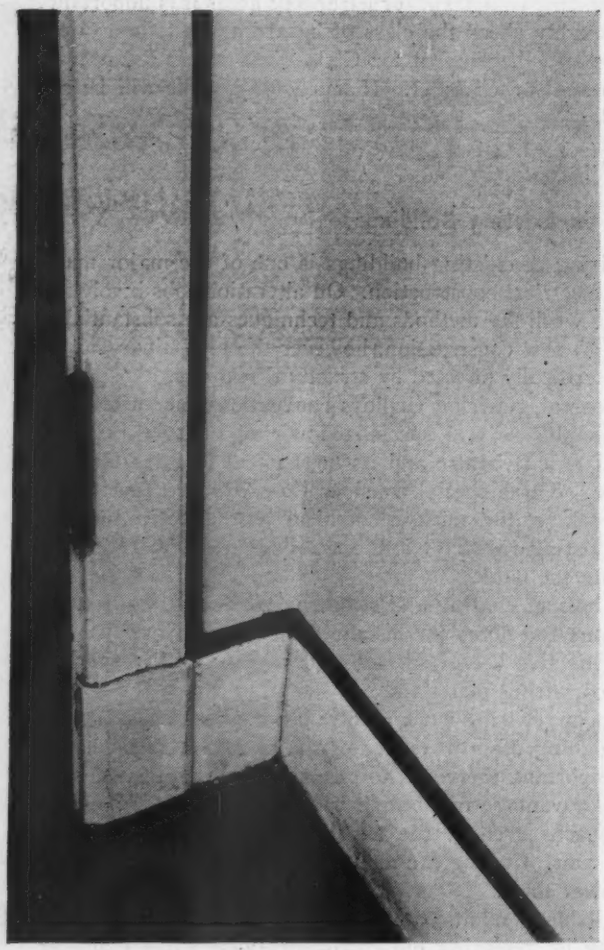
In general, rewiring employs conventional materials and methods plus several specialized wiring materials closely adapted to a structure and its mechanical features already in place. Three special considerations are involved:

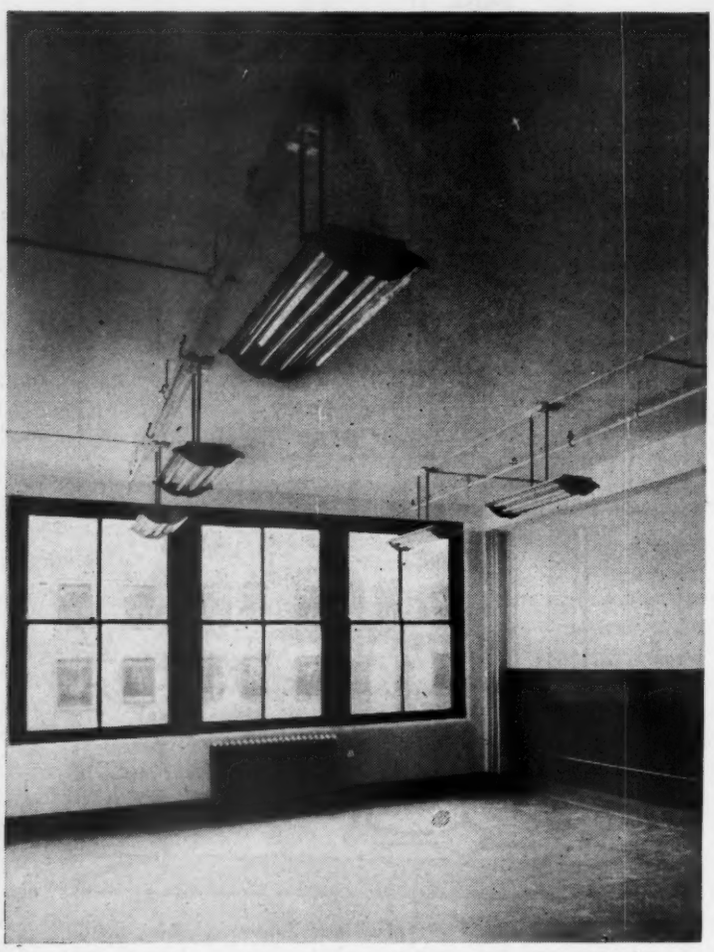
1) Making the most economical and effective use of existing raceways and accessible spaces for concealing the work.
2) Cutting, chasing and replacing partitions, walls, ceilings and floors for installing the new wiring.
3) Effective use of surface raceways and other specialized wiring materials.

Costs of rewiring work involve large amounts for cutting and patching often in excess of the actual electrical work. It is important, therefore, to plan the work with great care to take advantage of existing raceways, and readily accessible spaces even at the expense of more materials and larger runs. Cutting can also be greatly speeded with modern power tools.

Available conduits can be increased in load carrying capacity by replacing old conductors with small diameter wires. Fixture relocation is provided by surface wiring

INDUSTRIAL POWER wiring using bus system, plug in connectors and conduit drops to individual machine locations.





REWIRING DUCT follows woodwork in hotel remodel (left) surface raceway connects fixtures in office remodel (right).

IN OCCUPIED AREAS installation techniques must adapt to surroundings. Here pallet lift-truck holds bus way in place.

extensions. Modern panelboard designs permit the installation of many more circuits in existing cabinets.

Feeder installation usually involves a major cutting job and conventional conduits and wires. Difficulties are often aggravated by the need for many offsets and bends when new feeders must avoid existing mechanical work. Much of this can be overcome by installing lengths of flexible conduit in the tight spots. Difficult pulls can be avoided by oversizing the conduit and by using plenty of pull boxes.

Two types of wiring originally designed for industrial work have found a place in rewiring, the square crossection wireway and enclosed busbar distribution systems. Both offer wide flexibility in design, easy assembly, convenient fitting and easy access for taps and terminals.

Vertical risers of bus ways require special care in supporting. The manufacturers engineering department should be consulted on such applications. Several fairly large projects have recently been completed using bus way risers and the method offers advantages on major rewiring jobs.

The ratio of materials to labor cost on rewiring work is sharply reduced from new building construction. Materials may be only 30 percent or even less on some work. As a result the selection of materials and the methods employed depend to a large extent on the ultimate effect upon the labor cost. A moderate saving in installation time, or in cutting and patching, can offset large differences in the cost of alternative wiring systems.

In industrial work and where allowable on appearance considerations conventional exposed wiring is customarily used as well as many special raceways and bus ways. Installation is substantially the same in existing buildings as in new structures. When the building is occupied, machinery in place or process in operation, materials handling and installation techniques are critically important since they must work in harmony with the surrounding operations.

Temporary Work

Construction projects require light and power for the use of the contractors during the erection of the structure. The uses include: safety lighting for public passageways, lighting for job offices and shops, lighting for basements, corridors and interior rooms and power for hoists, machines and hand tools used by the contractors.

Temporary wiring may be a part of the electrical contract, a separately negotiated contract with the owners, a part of the general contract, or provided and billed to the individual contractors as they request it.

The work is of sufficient importance to be a formal part of the electrical work and this method is preferred. One hitch, however, is the need for early action often before all contracts are closed. Under such circumstances the preliminary safety lighting is negotiated separately.

Local building ordinances often specify the wiring standards to be observed in temporary wiring. In areas accessible to the public the requirements are those of conventional exposed wiring in metal raceways. In interiors requirements are N.E.C. standards with some leeway on fastenings.

Temporary work considerations are, in practice, much the same as permanent wiring. The facilities must be safe from fire and shock hazards, reasonably adequate for the expected loads and readily accessible for convenient use. It must also be protected from mechanical injury. Other special considerations obtain, however, which affect the choice of materials and methods. Working personnel will be reasonably alert adults and the installation is under constant surveillance of skilled electricians.

Service may be installed open on a temporary pole line to a job office or shop building or to weather-proofed meter and main switch on the terminal pole. Often underground service provisions are made during the pouring of the basement walls. A temporary service can then be pulled in and the entrance equipment mounted near the location of the permanent service. It is important however, to locate the temporary work out of the way of permanent switchboard and service equipment to avoid unnecessary shut downs for relocation.

A load approximation for temporary lighting is 1 watt per square foot of floor area and power at probable connected horsepower. To this must be added specific known loads such as hoists, pumps, shop lighting and heating.

Feeders are conventional. They are run in flexible conduit or open on insulators. Usual practice is to run one riser type with cord receptacles are used to provide plug-in.

Branch circuits are armoured cable, nonmetallic sheath cable or knob and tube wiring. Boxes are often omitted on nonmetallic jobs and weatherproof pigtail sockets connected directly to the cable. Drop cords of the rubber jacketed type with cord receptacles are used to provide plug-in

Extension cords are furnished by the contractors requiring them but good practice gives the electrician authority over their use and condition of repair. Cords on construction work receive the worst kind of abuse. Worn out, damaged cords and connectors are a source of waste time and hazard far beyond their cost.

In basement and wet locations, temporary wiring should provide for effective grounding of portable tools through 1) metal clad wiring or separate grounding wire, 2) three wire connectors and 3) three wire extension cords. Standardizing on three wire connectors throughout the temporary wiring is also an effective way of policing the system against haywire extensions by other trades.

Materials for temporary wiring are often salvaged or previously used. The practice is subject to question particularly on wires, sockets and connectors subject to much wear and tear. Labor costs for repairing and patching old materials can outweigh material cost considerations.

Good lighting, convenient and reliable power are just as important on a construction job as any other industrial operation even though the work must necessarily be of a temporary nature.

METHODS... USEFUL TABLES

VOLTAGE DROP TABLE

1. To find the size of wire required for a given voltage drop stated in percentage of the line voltage:

Find the "ampere-feet" by multiplying the current in amperes by the length of one wire in feet (not the total length of wire in the circuit).

Find the line voltage in the upper left corner; follow this horizontal line to the right to the given percent drop, follow this column down to the number of ampere-feet nearest to the actual number calculated. Follow this horizontal line to the left. The required size is the size found on this line.

2. To find the percent voltage drop which will be produced by a given size of wire:

Find the ampere-feet as above.

Starting with the given size of wire follow this horizontal line to the right to the number of ampere-feet nearest to the actual number calculated. Follow this column up to the percent drop on the line corresponding to the line voltage.

Volts	PERCENT DROP										
550	4	2	1.6	1.4	1.2	1.0	0.8	0.6	0.4	.....	.....
440	5	2.5	2	1.75	1.5	1.25	1	0.75	0.5	.....	.....
220	10	5	4	3.5	3	2.5	2	1.5	1	0.75	0.5
110	20	10	8	7	6	5	4	3	2	1.5	1

SIZE OF WIRE	AMPERES — FEET (AMPS × SINGLE DISTANCE IN FEET)										
14	.....	.....	1,670	1,460	1,250	1.050	840	630	420	310	210
12	.....	.....	2,660	2,320	1,990	1,660	1,330	1,000	670	500	330
10	10,600	5,300	4,200	3,700	3,170	2,650	2,120	1,590	1,060	790	530
8	16,800	8,400	6,700	5,900	5,000	4,200	3,400	2,520	1,680	1,260	840
6	26,700	13,400	10,700	9,400	8,000	6,700	5,300	4,000	2,670	2,010	1,340
5	33,700	16,900	13,500	11,800	10,100	8,400	6,700	5,100	3,370	2,530	1,690
4	42,500	21,300	17,000	14,900	12,800	10,600	8,500	6,400	4,300	3,200	2,130
3	53,600	26,800	21,400	18,800	16,100	13,400	10,700	8,000	5,400	4,000	2,680
2	67,600	33,800	27,000	23,700	20,300	16,900	13,500	10,100	6,800	5,100	3,400
1	85,200	42,600	34,100	29,800	25,600	21,300	17,000	12,800	8,500	6,400	4,300
0	107,500	53,800	43,100	37,600	32,300	26,900	21,500	16,100	10,800	8,100	5,400
00	135,500	67,800	54,200	47,400	40,700	33,900	27,100	20,300	13,600	10,200	6,800
000	170,900	85,500	68,400	59,800	51,300	42,700	34,200	25,600	17,100	12,800	8,500
0000	215,500	107,800	86,200	75,400	64,700	53,900	43,100	32,300	21,600	16,200	10,800
250,000 c.m.	254,600	127,300	101,900	89,100	76,400	63,700	50,900	38,200	25,500	19,100	12,700
300,000 c.m.	305,600	152,800	122,200	106,900	91,700	76,400	61,100	45,800	30,600	22,900	15,300
350,000 c.m.	356,500	178,200	142,600	124,800	106,900	89,100	71,300	53,500	35,600	26,700	17,800
400,000 c.m.	407,400	203,700	163,000	142,600	122,200	101,900	81,500	61,100	40,700	30,600	20,400
450,000 c.m.	458,300	229,200	183,300	160,400	137,500	114,600	91,700	68,700	45,800	34,400	22,900
500,000 c.m.	509,300	254,600	203,700	178,200	152,800	127,300	101,900	76,400	50,900	38,200	25,500

RIGID METAL CONDUIT—WEIGHTS AND DIMENSION

Conduit								Elbows			
Trade size, inches	Length	Nominal weight, pounds per foot	External diameter, inches	Nominal internal diameter, inches	Nominal wall thickness inches	Minimum weight 10 lengths, pounds	Threads per inch	Nominal weight, pounds per 100	Dimensions, inches		
									Radius	Ends	C/L to End
½	9' 11½"	0.852	0.840	0.622	0.109	79	14	83	4	2½	6½
¾	9' 11½"	1.134	1.050	0.824	0.113	105	14	123	4½	2¾	7¼
1	9' 11½"	1.684	1.315	1.049	0.133	153	11½	203	5¾	2⅞	8⅜
1¼	9' 11"	2.281	1.660	1.380	0.140	201	11½	318	7¼	2¾	10
1½	9' 11"	2.731	1.900	1.610	0.145	249	11½	432	8¼	2¾	11
2	9' 11"	3.678	2.375	2.067	0.154	334	11½	705	9½	4⅛	13⅝
2½	9' 10½"	5.819	2.875	2.469	0.203	527	8	1,261	10½	5 3/16	15 11/16
3	9' 10½"	7.616	3.500	3.068	0.216	690	8	1,840	13	4¾	17¾
3½	9' 10"	9.202	4.000	3.548	0.226	831	8	2,530	15	5	20
4	9' 10"	10.889	4.500	4.026	0.237	982	8	3,176	16	5 5/16	21 5/16
4½	9' 10"	12.642	5.000	4.506	0.247	1,150	8	4,110	18	5½	23½
5	9' 9"	14.810	5.563	5.047	0.258	1,344	8	6,170	24	5	29
6	9' 9"	19.185	6.625	6.065	0.280	1,770	8	9,590	30	6½	36½

NUMBER OF COMDUCTORS IN CONDUIT OR TUBING

Rubber Covered, Types RF-32, R, RH, RW and RU Thermoplastic, Types TF, T and TW One to Nine Conductors

Size AWG MCM	Number of Conductors in one Conduit or Tubing								
	1	2	3	4	5	6	7	8	9
18	½	½	½	½	½	½	½	¾	¾
16	½	½	½	½	½	½	¾	¾	¾
14	½	½	½	½	¾	¾	1	1	1
12	½	½	½	¾	¾	1	1	1	1¼
10	½	¾	¾	¾	1	1	1	1¼	1¼
8	½	¾	¾	1	1¼	1¼	1¼	1½	1½
6	½	1	1	1¼	1½	1½	2	2	2
4	½	1¼	*1¼	1½	1½	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1¼	2	2	2	2½	2½	2½
1	¾	1½	1½	2	2½	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	¼	2	2½	3	3	3	3½	3½	4
250	1¼	2½	2½	3	3	3½	4	4	4½
300	1¼	2½	2½	3	3½	4	4	4½	4½
350	1¼	3	3	3½	3½	4	4½	4½	5
400	1½	3	3	3½	4	4	4½	5	5
500	1½	3	3	3½	4	4½	5	5	6
600	2	3½	3½	4	4½	5	6	6	6
700	2	3½	3½	4½	5	5	6	6	...
750	2	3½	3½	4½	5	6	6	6	...
800	2	3½	4	4½	5	6	6	...	...
900	2	4	4	5	6	6	6	...	...
1000	2	4	4	5	6	6	...	...	...
1250	2½	4½	4½	6	6	...	...	...	...
1500	3	5	5	6	...	...	...	...	...
1750	3	5	6	6	...	...	...	...	...
2000	3	6	6	...	...	...	...	...	...

* Where a service run of conduit or electrical metallic tubing does not exceed 50 feet in length and does not contain more than the equivalent of two quarter bends from end to end two No. 4 insulated and one No. 4 bare conductors may be installed in 1-inch conduit or tubing.

NUMBER OF CONDUCTORS IN CONDUIT OR TUBING

Lead-Covered Types RL and RHL-600 V.

Size AWG MCM	Number of Conductors in One Conduit or Tubing											
	Single Conductor Cable				2-Conductor Cable				3-Conductor Cable			
	1	2	3	4	1	2	3	4	1	2	3	4
14	½	¾	¾	1	¾	1	1	1¼	¾	1¼	1½	1½
12	½	¾	¾	1	¾	1	1¼	1¼	1	1¼	1½	2
10	½	¾	1	1	¾	1¼	1¼	1½	1	1½	2	2
8	½	1	1¼	1½	1	1¼	1½	2	1	2	2	2½
6	¾	1¼	1½	1½	1¼	1½	2	2½	1¼	2½	3	3
4	¾	1¼	1½	1½	1¼	2	2½	2½	1½	3	3	3½
3	¾	1¼	1½	2	1¼	2	2½	3	1½	3	3	3½
2	1	1¼	1½	2	1¼	2	2½	3	1½	3	3½	4
1	1	1½	2	2	1½	2½	3	3½	2	3½	4	4½
0	1	2	2	2½	2	2½	3	3½	2	4	4½	5
00	1	2	2	2½	2	3	3½	4	2½	4	4½	5
000	1¼	2	2½	2½	2	3	3½	4	2½	4½	4½	6
0000	1¼	2½	2½	3	2½	3	3½	4½	3	5	6	6
250	1¼	2½	3	3	..	..	..	..	3	6	6	..
300	1½	3	3	3½	..	..	..	..	3½	6	6	..
350	1½	3	3	3½	..	..	..	..	3½	6	6	..
400	1½	3	3	3½	..	..	..	..	3½	6	6	..
500	1½	3	3½	4	..	..	..	..	4	6	..	..
600	2	3½	4	4½	..	..	..	..	..	..	..	..
700	2	4	4	5	..	..	..	..	..	..	..	..
750	2	4	4	5	..	..	..	..	..	..	..	..
800	2	4	4½	5	..	..	..	..	..	..	..	..
900	2½	4	4½	5	..	..	..	..	..	..	..	..
1000	2½	4½	4½	6	..	..	..	..	..	..	..	..
1250	3	5	5	6	..	..	..	..	..	..	..	..
1500	3	5	6	6	..	..	..	..	..	..	..	..
1750	3	6	6	..	..	..	..	..	..	..	..	..
2000	3½	6	6	..	..	..	..	..	..	..	..	..

Useful Tables Continued →

COMBINATION OF CONDUCTORS

Per Cent Area of Conduit or Tubing Occupied by Conductors

	Number of Conductors				
	1	2	3	4	Over 4
Conductors (not lead covered)	53	31	43	40	40
Lead-covered conductors	55	30	40	38	35
For rewiring existing raceways for increased load where it is impracticable to increase the size of the raceway due to structural conditions	60	40	50	50	50

DIMENSIONS OF CONDUIT OR TUBING

Size	Internal Diameter Inches	Area Square Inches	Size	Internal Diameter Inches	Area Square Inches
½	.622	.30	3	3.068	7.38
¾	.824	.53	3½	3.548	9.90
1	1.049	.86	4	4.026	12.72
1¼	1.380	1.50	4½	4.506	15.95
1½	1.610	2.04	5	5.047	20.00
2	2.067	3.36	6	6.065	28.89
2½	2.469	4.79			

ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Not More Than Three Conductors in Raceway or Cable

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermoplastic Type T (14–410) Type TW (14–410)	Rubber Type RH	Paper / Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
0	125	150	155	190	200	225
00	145	175	185	215	230	250
000	165	200	210	245	265	285
0000	195	230	235	275	310	340
250	215	255	270	315	335	....
300	240	285	300	345	380	....
350	260	310	325	390	420	....
400	280	335	360	420	450	....
500	320	380	405	470	500	....
600	355	420	455	525	545	....
700	385	460	490	560	600	....
750	400	475	500	580	620	....
800	410	490	515	600	640	....
900	435	520	555	...	...	....
1000	455	545	585	680	730	....
1250	495	590	645	...	...	....
1500	520	625	700	785	...	....
1750	545	650	735	...	...	....
2000	560	665	775	840	...	....

ALLOWABLE CURRENT-CARRYING CAPACITIES OF CONDUCTORS IN AMPERES

Single Conductor in Free Air

(Based on Room Temperature of 30 C. 86 F.)

Size AWG MCM	Rubber Type R Type RW Type RU (14–6) / Thermoplastic Type T Type TW	Rubber Type RH	Thermoplastic Asbestos Type TA / Var-Cam Type V / Asbestos Var-Cam Type AVB	Asbestos Var-Cam Type AVA Type AVL	Impregnated Asbestos Type AI (14–8) Type AIA	Asbestos Type A (14–8) Type AA	Slow Burning Type SB / Weatherproof Type WP Type SBW
14	20	20	30	40	40	45	30
12	25	25	40	50	50	55	40
10	40	40	55	65	70	75	55
8	55	65	70	85	90	100	70
6	80	95	100	120	125	135	100
4	105	125	135	160	170	180	130
3	120	145	155	180	195	210	150
2	140	170	180	210	225	240	175
1	165	195	210	245	265	280	205
0	195	230	245	285	305	325	235
00	225	265	285	330	355	370	275
000	260	310	330	385	410	430	320
0000	300	360	385	445	475	510	370
250	340	405	425	495	530	....	410
300	375	445	480	555	590	....	460
350	420	505	530	610	655	....	510
400	455	545	575	665	710	....	555
500	515	620	660	765	815	....	630
600	575	690	740	855	910	....	710
700	630	755	815	940	1005	....	780
750	655	785	845	980	1045	....	810
800	680	815	880	1020	1085	....	845
900	730	870	940	....	.....	....	905
1000	780	935	1000	1165	1240	....	965
1250	890	1065	1130	....	.....	....	.....
1500	980	1175	1260	1450	.....	....	1215
1750	1070	1280	1370	....	.....	....	.....
2000	1155	1385	1470	1715	.....	....	1405

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C.	F.						
40	104	.82	.88	.90	.94	.95	....
45	113	.71	.82	.85	.90	.92	....
50	122	.58	.75	.80	.87	.89	....
55	131	.41	.67	.74	.83	.86	....
60	140	....	.58	.67	.79	.83	.91
70	158	....	.35	.52	.71	.76	.87
75	167	....	...	.43	.66	.72	.86
80	176	....	...	.30	.61	.69	.84
90	194	....	...	....	.50	.61	.80
100	212	....	...	....	...	.51	.77
120	248	....	...	....	...	...	.69
140	284	....	...	....	...	...	.59

CORRECTION FACTOR FOR ROOM TEMPERATURES OVER 30 C. 86 F.

C.	F.							
40	104	.82	.88	.90	.94	.95	....	.....
45	113	.71	.82	.85	.90	.92	....	.....
50	122	.58	.75	.80	.87	.89	....	.....
55	131	.41	.67	.74	.83	.86	....	.....
60	140	.....	.58	.67	.79	.83	.91	.....
70	158	.....	.35	.52	.71	.76	.87	.....
75	167	.....	....	.43	.66	.72	.86	.....
80	176	.....	....	.30	.61	.69	.84	.....
90	194	.....	....	.....	.50	.61	.80	.....
100	212	.....	....	.....	....	.51	.77	.....
120	248	.....	....	.....	....	.....	.69	.....
140	284	.....	....	.....	....	.....	.59	.....

DIMENSIONS OF RUBBER-COVERED AND THERMOPLASTIC-COVERED CONDUCTORS

Size AWG MCM	Types RF-32, R, RH, RW		Types TF, T, TW, RU**	
	Approx. Diam. Inches	Approx. Area Sq. Ins.	Approx. Diam. Inches	Approx. Area Sq. Ins.
18	.146	.0167	.106	.0088
16	.158	.0196	.118	.0109
14	2/64 in. .171	.0230	.131	.0135
14	3/64 in. .204*	.0327*		
12	2/64 in. .188	.0278	.148	.0172
12	3/64 in. .221*	.0384*		
10	.242	.0460	.168	.0224
8	.311	.0760	.228	.0408
6	.397	.1238	.323	.0819
4	.452	.1605	.372	.1087
3	.481	.1817	.401	.1263
2	.513	.2067	.433	.1473
1	.588	.2715	.508	.2027
0	.629	.3107	.549	.2367
00	.675	.3578	.595	.2781
000	.727	.4151	.647	.3288
0000	.785	.4840	.705	.3904
250	.868	.5917	.788	.4877
300	.933	.6837	.843	.5581
350	.985	.7620	.895	.6291
400	1.032	.8365	.942	.6969
500	1.119	.9834	1.029	.8316
600	1.233	1.1940	1.143	1.0261
700	1.304	1.3355	1.214	1.1575
750	1.339	1.4082	1.249	1.2252
800	1.372	1.4784	1.282	1.2908
900	1.435	1.6173	1.345	1.4208
1000	1.494	1.7531	1.404	1.5482
1250	1.676	2.2062	1.577	1.9532
1500	1.801	2.5475	1.702	2.2748
1750	1.916	2.8895	1.817	2.5930
2000	2.021	3.2079	1.922	2.9013

* The diameters of Type RW in Nos. 14 and 12 are .204 .221, respectively, and he areas are .0327 and .0384, respectively.
** Type RV conductors recognized in sizes No. 14 to No. 6, No. 18 to No. 8, solid; No. 6 and larger, stranded.

DIMENSIONS OF LEAD-COVERED CONDUCTORS

Types RL and RHL

Size AWG-MCM	Single Conductor		Two Conductor		Three Conductor	
	Diam. Inches	Area Sq. Ins.	Diam. Inches	Area Sq. Ins.	Diam. Inches	Area Sq. Ins.
14	.28	.062	.28 x .47	.115	.59	.273
12	.29	.066	.31 x .54	.146	.62	.301
10	.35	.096	.35 x .59	.180	.68	.363
8	.41	.132	.41 x .71	.255	.82	.528
6	.49	.188	.49 x .86	.369	.97	.738
4	.55	.237	.54 x .96	.457	1.08	.916
2	.60	.283	.61 x 1.08	.578	1.21	1.146
1	.67	.352	.70 x 1.23	.756	1.38	1.49
0	.71	.396	.74 x 1.32	.859	1.47	1.70
00	.76	.454	.79 x 1.41	.980	1.57	1.94
000	.81	.515	.84 x 1.52	1.123	1.69	2.24
0000	.87	.593	.90 x 1.64	1.302	1.85	2.68
250	.98	.754	.....	....	2.02	3.20
300	1.04	.85	.....	....	2.15	3.62
350	1.10	.95	.....	....	2.26	4.02
400	1.14	1.02	.....	....	2.40	4.52
500	1.23	1.18	.....	....	2.59	5.28

ISOLATION BY ELEVATION

Distance of Live Parts Above the Floor or Other Working Surface

Voltage Between Phases	Minimum Vertical Clearance of Unguarded Parts Feet	Inches
600	8	0
2300	8	0
6600	8	0
11000	9	0
22000	9	3
33000	9	6
44000	9	10
66000	10	5
88000	11	0
110000	11	7
132000	12	2

WORKING SPACE

Minimum Clear Space Adjacent to Live Parts

Voltage Between Phases	Minimum Horizontal Clearance of Unguarded Parts Feet	Inches
600	3	2
2300	3	3
6600	3	4
11000	3	6
22000	3	9
33000	4	0
44000	4	4
66000	4	11
88000	5	6
110000	6	1
132000	6	8

NUMBER OF CONDUCTORS IN CONDUIT OR TUBING

More Than Nine Conductors
Rubber-Covered Types RF-32, R, RH, RW, RU
Thermoplastic Types TF, T, and TW

Size AWG	Maximum Number of Conductors in Conduit or Tubing						
	¾ Inch	1 Inch	1¼ Inch	1½ Inch	2 Inch	2½ Inch	3 Inch
18	12	20	35	49	80	115	176
16	10	17	30	41	68	97	150
14		10	18	25	40	59	90
12			15	21	35	50	77
10			13	17	29	41	64
8				10	17	25	38
6						15	23

Useful Tables Continued

Useful Tables Concluded

ELECTRICAL METALLIC TUBING—WEIGHTS AND DIMENSIONS

Sizes, inches	Approximate weight per 1000 ft., pounds	Diameter inches	
		Internal	External
⅜	254	0.493	0.577
½	321	0.622	0.706
¾	488	0.824	0.922
1	711	1.049	1:163
1¼	985	1.380	1.508
1½	1141	1.610	1.738
2	1470	2.067	2.195

SINGLE TELEPHONE CABLE

No. Cond.	Single No. 22 & 4 Single No. 18					
	Braided			Leaded		
	Over. Diam.	Approx. Area Sq. In.	Cond. Size	Over. Diam.	Approx. Area Sq. In.	Cond. Size
6	0.26	0.053	½"	0.30	0.071	½"
11	0.28	0.061	½"	0.33	0.086	½"
16	0.31	0.075	½"	0.36	0.102	½"
26	0.36	0.102	½"	0.40	0.126	¾"
35	0.40	0.126	¾"	0.45	0.159	¾"
45	0.44	0.152	¾"	0.48	0.181	¾"
55	0.46	0.165	¾"	0.51	0.204	¾"
65	0.51	0.204	¾"	0.55	0.236	1"
75	0.53	0.219	1"	0.59	0.255	1"
85	0.55	0.236	1"	0.60	0.283	1"
100	0.60	0.283	1"	0.64	0.322	1"

CONVERSION FORMULAS

To Find the Value	When Value Below is Known	SYSTEM			
		Direct Current	Single-Phase	Two-Phase Four Wire	Three-Phase
		FORMULAE			
Amperes (I)	Horsepower (hp)	$I = \frac{746\ hp}{E \times eff}$	$I = \frac{746\ hp}{E \times eff \times pf}$	$I = \frac{746\ hp}{2E \times eff \times pf}$	$I = \frac{746\ hp}{1.73E \times eff \times pf}$
Amperes (I)	Kilowatts (kw)	$I = \frac{1000\ kw}{E}$	$= \frac{1000\ kw}{E \times pf}$	$I = \frac{1000\ kw}{2E \times pf}$	$I = \frac{1000\ kw}{1.73E \times pf}$
Amperes (I)	Kilovolt-Amperes (kva)		$I = \frac{1000\ kva}{E}$	$I = \frac{1000\ kva}{2E}$	$I = \frac{1000\ kva}{1.73E}$
Kilowatts (kw) Input		$kw = \frac{I \times E}{1000}$	$kw = \frac{I \times E \times pf}{1000}$	$kw = \frac{I \times E \times 2 \times pf}{1000}$	$kw = \frac{I \times E \times 1.73 \times pf}{1000}$
Kilovolt-Amperes (kva)			$kva = \frac{I \times E}{1000}$	$kva = \frac{I \times E \times 2}{1000}$	$kva = \frac{I \times E \times 1.73}{1000}$
Horsepower (hp) Output		$hp = \frac{I \times E \times eff}{746}$	$hp = \frac{I \times E \times eff \times pf}{746}$	$hp = \frac{I \times E \times 2 \times eff \times pf}{746}$	$hp = \frac{I \times E \times 1.73 \times eff \times pf}{746}$

I = Amperes.
E = Volts.
eff = Efficiency in decimals.
pf = Power Factor in decimals.

kw = Kilowatts Input.
kva = Kilovolt-Amperes Input.
hp = Horsepower Output.

For two-phase, three wire, balanced circuits the amperes in common conductor = 1.41 X that in either of the other two.

PAIR TELEPHONE CABLE

No. Pairs	Pairs No. 22 & 2 Pairs No. 18						Pairs No. 22 Only					
	Braided			Leaded			Braided			Leaded		
	Over. Diam.	Approx. Area Sq. In.	Cond. Size	Over. Diam.	Approx. Area Sq. In.	Cond. Size	Over. Diam.	Approx. Area Sq. In.	Cond. Size	Over. Diam.	Approx. Area Sq. In.	Cond. Size
6	0.36	0.102	½"	0.45	0.159	¾"	0.29	0.066	½"	0.33	0.086	½"
12	0.41	0.132	¾"	0.50	0.196	¾"	0.38	0.113	½"	0.42	0.139	¾"
16	0.50	0.196	¾"	0.59	0.273	1"	0.42	0.139	¾"	0.47	0.174	¾"
22	0.57	0.255	1"	0.66	0.342	1"	0.49	0.188	¾"	0.53	0.220	1"
32	0.62	0.302	1"	0.71	0.396	1¼"	0.57	0.253	1"	0.61	0.292	1"
41	0.74	0.430	1¼"	0.85	0.567	1¼"	0.61	0.292	1"	0.66	0.342	1"
51	0.88	0.608	1½"	0.97	0.739	1½"	0.70	0.385	1¼"	0.76	0.454	1¼"
65	0.92	0.665	1½"	1.01	0.802	2"	0.76	0.454	1¼"	0.83	0.541	1¼"
75	0.95	0.709	1½"	1.03	0.833	2"	0.82	0.528	1¼"	0.89	0.622	1½"
85	0.98	0.754	1½"	1.07	0.899	2"	0.86	0.581	1¼"	0.93	0.679	1½"
100	1.08	0.916	2"	1.16	1.057	2"	0.94	0.694	1½"	1.01	0.802	1½"
125	1.18	1.094	2"	1.26	1.247	2"	1.01	0.802	1½"	1.08	0.916	2"
150	1.27	1.254	2"	1.34	1.410	2½"	1.12	0.985	2"	1.18	1.094	2"
175	1.37	1.474	2½"	1.44	1.624	2½"	1.18	1.094	2"	1.25	1.227	2"
200	1.45	1.649	2½"	1.57	1.938	3"	1.27	1.254	2"	1.34	1.410	2½"

GROUPED SINGLE CONDUCTORS

Size AWG	Insulation R-32, R, RH, RW*		Insulation TF, T, TW, RU*		Insulation RF-64**		Maximum Number Conductors in Conduit						
	Over. Diam.	Approx. Area Sq. In.	Over. Diam.	Approx. Area Sq. In.	Over. Diam.	Approx. Area Sq. In.	½ in. Int. Area .30 Sq. In.	¾ in. Int. Area .53 Sq. In.	1 in. Int. Area .86 Sq. In.	1¼ in. Int. Area 1.50 Sq. In.	1½ in. Int. Area 2.04 Sq. In.	2 in. Int. Area 3.36 Sq. In.	2½ in. Int. Area 4.79 Sq. In.
18	.146	.0167	.106	.0088			7	12	20	35	49	80	115
18					.100	.0079	14	24	42	73	100	165	236
16	.158	.0196	.118	.0109			6	10	17	30	41	68	97
16					.113	.0100	12	19	33	58	79	131	186
14	.171	.0230	.131	.0135			4	6	10	18	25	40	59
12	.188	.0278	.148	.0172			3	5	8	15	21	35	50
10	.242	.0460	.168	.0224			2	4	7	13	17	29	41
8	.311	.0760	.228	.0408			1	3	4	7	10	17	25
6	.397	.1238	.323	.0819			1	1	3	4	6	9	15

Combination of Conductors

*		**	
1—No. 14 Equal to		1—No. 18 or 1 No. 16	
2— " " " "		2— " " " 2 " "	
3— " " " "		4— " " " 3 " "	
1— " 12 " "		1— " " " 1 " "	
2— " " " "		3— " " " 3 " "	
3— " " " "		4— " " " 4 " "	
		3—No. 18 or 2 No. 16	
		5— " " " 4 " "	
		8— " " " 7 " "	
		3— " " " 3 " "	
		7— " " " 5 " "	
		10— " " " 8 " "	

Note: * In accordance with NEC.
** Approved by special permission.

Above sizes apply straight runs or with equivalent to not more than two quarter-bends

Advertisers' Product Index

ELECTRICAL CONSTRUCTION & MAINTENANCE • JULY, 1948

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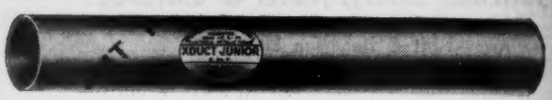

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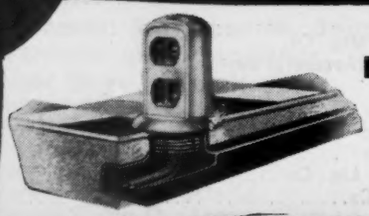

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Changing Characteristics of D-C Generators

Concluding a series of two articles on d-c generators, the author tells how to vary generator operating characteristics.

By Warren W. Gregory
Westinghouse Electric Corporation, St. Louis, Missouri

THE manufacturer's nameplate on a d-c generator is the key to the operating characteristics of the machine. The nameplate gives the kilowatt load rating, the terminal voltage, the line current, the driven rpm., the main field pole winding, a time-temperature rise which the generator will not exceed while carrying rated nameplate load, and the manufacturer's identifying serial numbers.

A change from one type of main field pole winding to that of another type is perhaps the simplest change that can be made to a d-c generator to change its operating characteristics. For instance, suppose we have a self-excited shunt wound generator which has a voltage regulation represented by curve (1), Fig. 7. Now suppose we want to move this generator to a new location and use the generator to supply power to a circuit which has both lighting and motor loads connected to it. If the new circuit supplied only motor loads, small variations in the generator output voltage wouldn't be of too much importance. However, since lights are connected to the assumed circuit, small variations in the circuit voltage will cause uneven lighting and be undesirable. Therefore, we would like to change the generator to have a regulation as represented by curve (3), Fig. 7.

To make this change, theoretically, all we need to do is add series coils to the generator. Practically, there may not be sufficient space around the shunt field coils of the generator to add series coils. In that case, it will be necessary to remove the existing shunt field coils and replace with both new shunt field coils and series coils especially designed for compound wound operation.

Whenever we make changes in the shunt field coil circuit, it is always a wise precaution to check the shunt field rheostat to be sure that the rheostat has the proper resistance value and current carrying capacity for the changed conditions.

The output voltage of a d-c generator can be changed by changing the driven rpm. As an illustration, assume we have available a shunt wound, self-excited, d-c generator, rated 100 kw., 250 volts, 1800 rpm. Also assume we need a shunt wound, self-excited generator to carry a 40 kw. load at 125 volts. Now, for rough estimating purposes, it is close enough to assume that the kw. output and the terminal voltage of a generator varies directly as the driven speed. Therefore, if we reduce the driven speed of the generator from 1800 rpm. down to 900 rpm., we should be able to get 50 kw. output at 125 volts from our 100 kw, 250 volt, 1800 rpm. generator. Actually, both the kw. output and the terminal voltage will be somewhat less than our estimated values at the reduced speed. Suppose we allow a 10 percent reduction in our estimated kw. output for decreased ventilation and we allow a 5 percent reduction in our estimated terminal voltage due to resistance drops inside the generator. (Incidentally, the percentage reductions used are reasonably correct for a 100 kw. generator.) Revising our first rough estimate, we should be able to rerate our generator, 45 kw., 119 volts rpm. Now, 119 volts is not considered a normal d-c operating voltage. Therefore, we have the choice of operating the generator at 119 volts or, slightly increasing the driven speed to raise the output voltage to 125 volts or, raising the voltage to 125 volts by increasing the shunt field current by about the same percentage that the voltage is low. In my opinion, the latter method is preferable, provided that the overexcitation does not increase the shunt field coil heating above a safe operating coil temperature. Usually, generator shunt field coils have a sufficient temperature margin to permit a 5 percent increase in the excitation current.

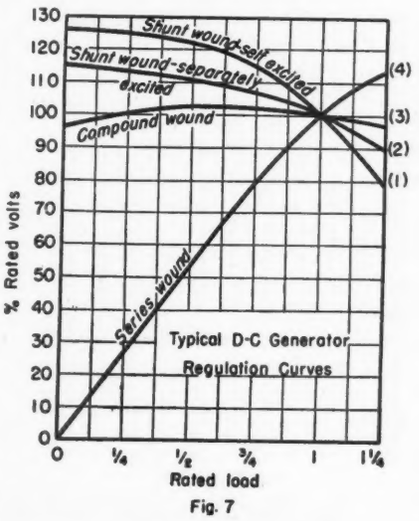
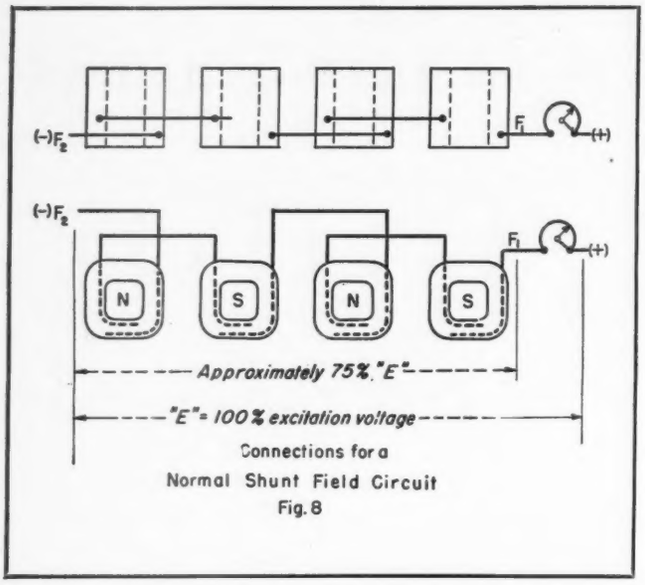


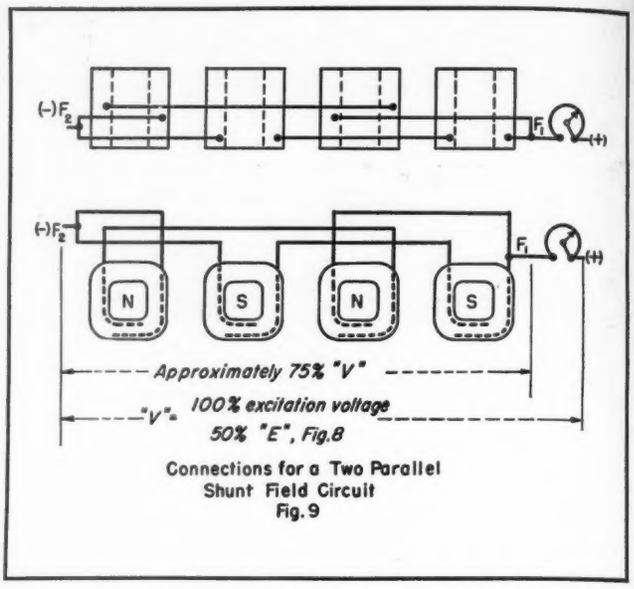
Fig. 7

A major change in the driven speed of a self-excited d-c generator necessitates a major change in the normal shunt field coil circuit, Fig. 8, if the generator is to remain self-excited.

Self-excited d-c generators are normally manufactured with a voltage drop across the shunt field circuit in the order of 75 percent of the rated



Connections for a
Normal Shunt Field Circuit
Fig. 8



Connections for a Two Parallel
Shunt Field Circuit
Fig. 9

terminal voltage. Therefore, if we change the terminal voltage from 250 volts to 125 volts, we will have insufficient voltage available to excite the shunt fields. Rather than replace the shunt field coils with new coils requiring less excitation voltage, it is customary to reconnect the original shunt field coils in two parallel circuits as per Fig. 9. This parallel connection drops the excitation voltage across the coils by 50 percent and increases the total shunt field current through the field rheostat to 200 percent of its former value. It is therefore reasonable to expect that a new field rheostat will be required having less total resistance and increased current carrying capacity.

Increasing the terminal voltage of a self-excited d-c generator, by increasing the driven rpm., does not require reconnecting the shunt field circuit. If the driven rpm. is increased more than 10 percent, it will probably be found that additional resistance will be needed in the shunt field circuit to extend the workable range of the field rheostat. The additional resistance can be a fixed resistor tube having a proper ohmic value and current carrying capacity. Connect the resistor in series with the shunt field and field rheostat, as per Fig. 10.

Decreasing the driven speed of rotating equipment below that given on the nameplate does not affect the mechanical strength of the driven machine. However, increasing the driven speed above that listed on the nameplate can be hazardous. All generators are manufactured to withstand rotating mechanical stresses at the nameplate speed, plus a margin of safety for overspeeds. Be sure and check the manufacturer and obtain his approval before arbitrarily increasing the driven speed of any piece of rotating equipment. This is safe advice. Be sure and follow it.

The output voltage of a d-c generator can be changed without changing the driven rpm. by replacing the armature and commutating coils with another armature and new commutating coils. The replacement armature may be a complete new armature or it may be the old armature core rewound with different armature coils. In either case, an armature change is really a design problem and the manufacturer should be consulted and his advice followed.

So far, we have discussed changing the operating characteristics of a d-c generator by substituting one type of main field winding for that of another type; by changing the driven rpm.; and by changing armatures. These changes are relatively easy to calculate and predict the expected generator performance.

Changes involving the magnetic circuit of a generator are definitely design changes and should only be made from specific information furnished by the manufacturer. The following information covering the use of main field pole notches is given only to convey to readers what can be done if the operating conditions justify the change.

Suppose we have two or more shunt wound generators which we want to operate in parallel. Now, shunt wound generators, either self-excited or separately excited, are the easiest kind of d-c generators to operate in parallel due to the definite drooping characteristic of the voltage regulation curve. See curves (1) & (2), Fig. 7. However, unless the generators have similar voltage regulation curves, that is, the regulation curves have the same

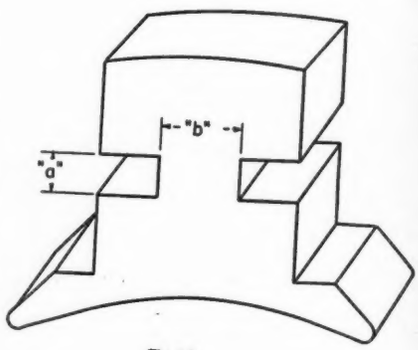
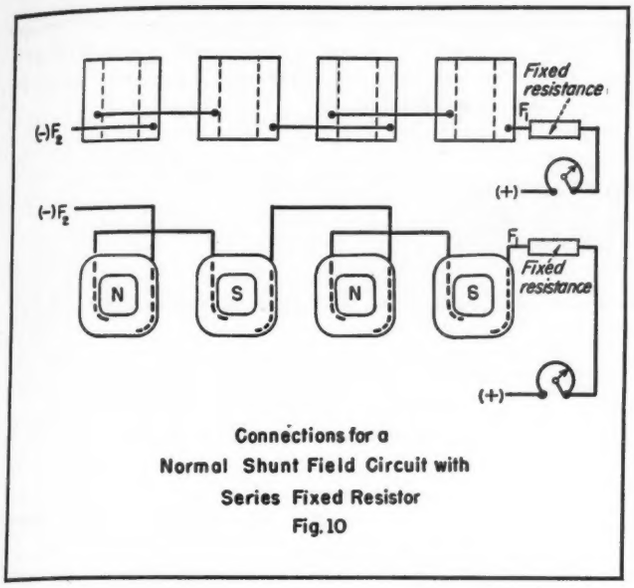


Fig. 12

general shape from no load to full load, the generators will not divide the connected load proportionately throughout the operating range. This can become a serious operating problem, especially if the generators differ greatly in size and rating and if the smaller rated generator tends to hog the total load at some point in the operating cycle.

The shape of a voltage regulation curve can be changed. We cannot materially increase the regulation of a generator without completely rebuilding the machine, but we can reduce the regulation of a generator by introducing magnetic saturation. Therefore, in approaching a paralleling problem which involves the shape of the regulation curves, we select the generator having the least amount of regulation as a base and modify the other generators so that their regulation curves conform to the regulation curve of the base generator.

The no load and full load saturation curves, Fig. 11, are typical of a normal d-c generator. The points "B" and "C" where the shunt field plus the field rheostat resistance line intersects the full load and no load sa



Connections for a
Normal Shunt Field Circuit with
Series Fixed Resistor
Fig. 10

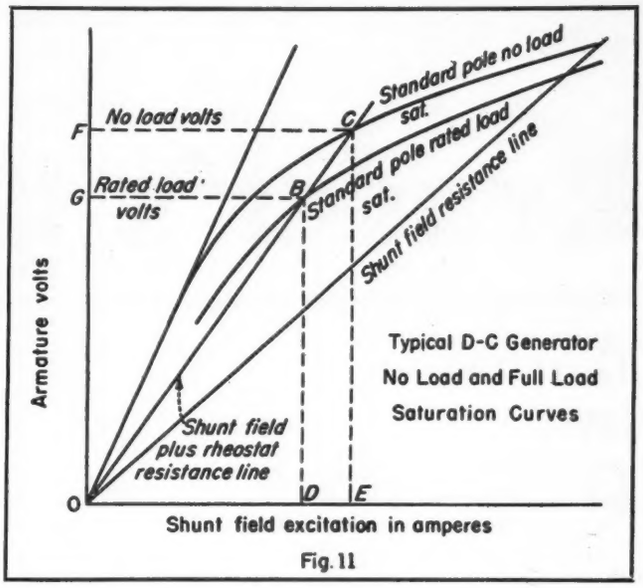


Fig. 11

uration curves determines the self-excited regulation of the generator. "OF" is the no load voltage of the generator and "OG" is the full load voltage of the generator.

Assume for our purposes, that the regulation of the generator, Fig. 11, must be reduced. Since the rated load voltage "OG" should remain the same, we must alter the generator so that the no load voltage "OF" is reduced. This can be done by introducing magnetic saturation at some point in the field magnetic circuit. This is usually accomplished by machining notches in the main field poles as indicated by Fig. 12. Since introducing magnetic saturation is a design change, dimensions "a" and "b" Fig. 12, should be obtained from the manufacturer.

Fig. 13, shows how notching the main field poles as per Fig. 12, affects the no load and full load saturation curves of a generator. The dashed no load and full load saturation curves are before notching the main poles and are included for comparison purposes. The new no load voltage is now "OF'" instead of "OF". Therefore regulation has been reduced.

Whenever main field poles are notched, increased shunt field excitation is required to overcome the magnetic saturation and maintain the same rated load generated voltage. This is indicated in Fig. 13 by an increase in shunt field excitation from "OD" to "OD'". This increase in shunt field excitation will increase the shunt field coil heating which should be checked, and if necessary other measures taken to avoid shunt field coil heating.

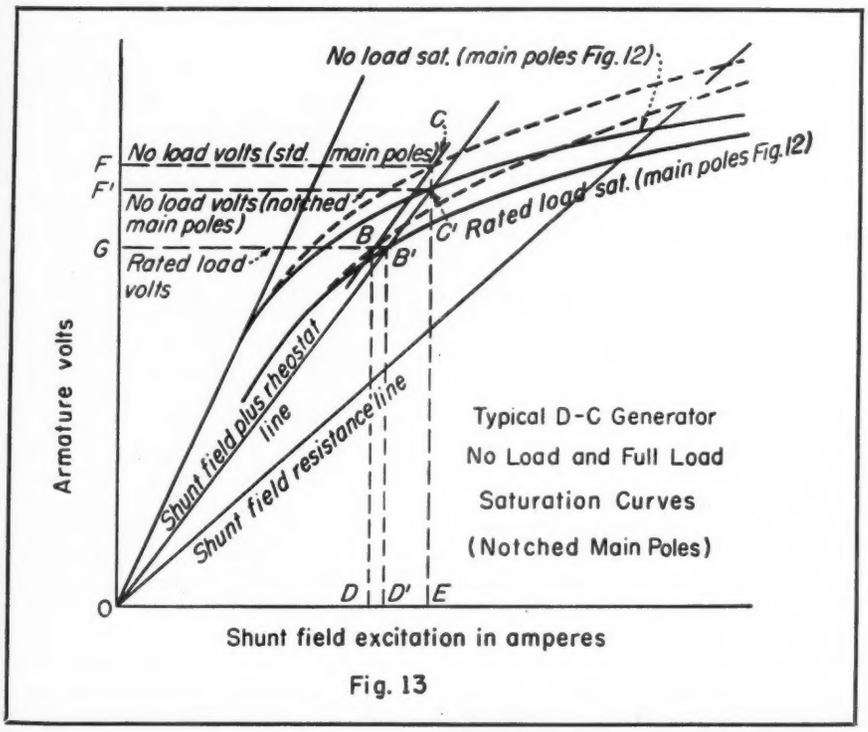

No load sat. (main poles Fig. 12)
No load volts (std. main poles)
No load volts (notched main poles)
Rated load volts
Rated load sat. (main poles Fig. 12)
Armature volts
Shunt field plus rheostat line
Shunt field resistance line
Typical D-C Generator
No Load and Full Load
Saturation Curves
(Notched Main Poles)
Shunt field excitation in amperes

Fig. 13

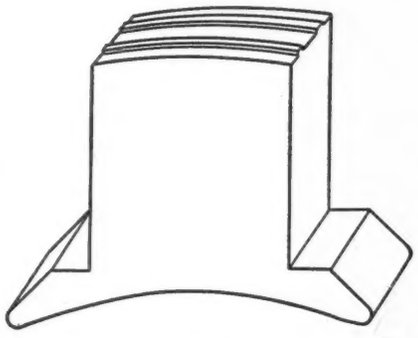


Fig. 14

Magnetic saturation is used to increase the stability of exciters when operating at voltage below the "Knee" of the saturation curve. Again, the magnetic saturation is introduced in the main field poles but a radial type notch Fig. 14, is used. You will note that the notch consists of small ridges machined on the back of the pole where the pole bolts to the frame. The relatively narrow ridges may vary approximately from $\frac{1}{4}$" to $1\frac{1}{2}$" in width and from $\frac{1}{16}$" to $\frac{1}{8}$" in depth. Again, this is a design problem and all information for changes should be obtained from the manufacturer.

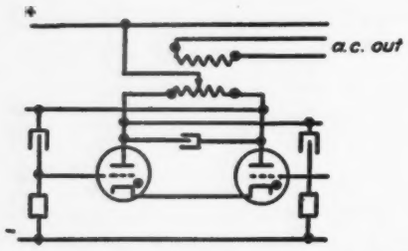
The changes described are the most common changes encountered in the field. Due to the flexibility of a d-c generator, there are many adjustments and other combination of special fields which can be used but not described in this article to alter the output of a d-c generator to meet special operating conditions.

QUESTIONS from readers on problems of industrial equipment, installation, maintenance and repair. Answered by electrical maintenance engineers and industrial electrical contractors out of their experience. For every question and every answer published, we pay $5.00.

Reader's Quiz

Thyratron Inverter

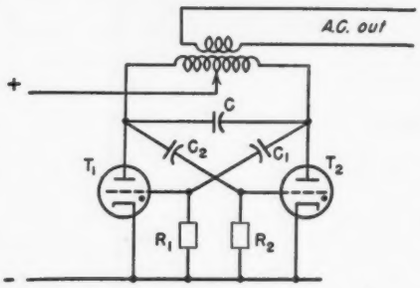
QUESTION 283—Below is a thyratron inverter diagram. Could someone explain how it is started



and the a-c frequency is controlled?—E.J.K.

A. TO QUESTION 283 — The diagram (next column) shows the same circuit slightly rearranged for simplicity and circuit elements are identified to help make a clear explanation. Also slight changes have been made to apparently correct the published diagram.

The slight inequalities in the circuit cause the tube to start when d-c is applied. Potential is applied to each anode. Also potential is applied to the capacitors C_1 and C_2. These capacitors start to charge through resistors R_1 and R_2. The potentials on the grids are changed and, because of circuit element inequalities, one tube will fire or conduct before the other. Assume tube T fires first; capacitor C would then prevent tube T_2 from firing while T_1 is conducting. Now, the negative charge on the grid side of C_2 cannot leak off, except through R_1 and through tube T_1 to the other plate of C_2. This requires a definite time. When this has leaked off sufficiently, tube T_2 will fire or conduct and stop T_1 and the circuit will thus alternate between tubes T_1 and T_2. The alternating flow of pulses of current in the two halves of the primary winding of transformer T will produce an a-c voltage on the transformer secondary. The frequency of the a-c output will be determined by the time necessary for charges to leak off C_1 and



C_2. Thus, frequency is primarily determined by the values of C_1, C_2, R_1, and R_2 and will be fairly constant and self controlled.—L.R.B.

A. TO QUESTION 283—Your diagram shows a parallel thyratron inverter but it is incomplete. The cathodes of both tubes should connect to the negative feed, and of course, there should also be a heater circuit. With the circuit complete, it is only necessary to connect the d-c input and connect the heater circuit which should be controlled with a switch and there will be an alternating current available at the a-c output, the frequency of which depends on the constants of the grid and anode circuits and varies with the d-c line voltage, the load current and power factor.—S.S.P.

A. TO QUESTION 283—When the tubes are controlled by d-c, the plate voltage must be reduced to zero and held there for a fraction of a second, this is accomplished by the primary of the transformer, half of which is in series with each plate and the line, its winding acting as an impedance. When the d-c, circuit is closed, one tube will conduct and one will not, due to the action of the condenser that ties the plates together. The grid in a gaseous tube is simply a relay or one-way control and its voltage must be lowered or the anode current will not flow. This is accomplished by the push-pull connection of the condensers in series with the resistors when the grid voltage is reduced. Until the critical voltage is obtained the full anode current will flow, which is only regulated by the impedance of the external load, the grid having no control over its magnitude. The current can be stopped only by lowering the plate voltage below the gas ionization potential. As a resistor in series with a condenser regulates the time of the condenser's charge and discharge, by the amount of resistance inserter, it's my opinion this principle is intended to regulate the frequency although a potentiometer would be more appropriate. The mechanical connection of cathode to negative has been omitted.—J.V.H.

A. TO QUESTION 283—With regard to diagram of thyratron inverter sent in by E.J.K., I first call attention to a connection evidently left out or not printed. There should be a connection between the lead joining the two cathodes and the negative d-c lead below it.

This unit is started by the application of the d-c potential. It is similar to a multivibrator in operation.

The inverter is a two-tube combination in which the output of the second tube is fed to the input of the first, to force it to cutoff when a critical point has been passed. In this circuit, the anodes of the two tubes feed into the two ends of a center-tapped transformer primary. Since the thyratrons cannot be extinguished by driving the grids negative, it is necessary to force the anode potential below the arc potential and hold it there long enough for the tube to deionize. This is done by connecting a fairly large capacitor between the two anodes. The anode of the thyratron that is conducting will be at a lower potential than the anode of the non-conducting tube, and the capacitor charges up accordingly. Then, as the second thyratron is caused to conduct, the potential of its anode is lowered and, by its connection through the capacitor, forces the first anode negative, while the capacitor discharges. While the anode is negative, the thyratron ceases to conduct and has a chance to deionize. The capacitor rapidly reverses its charge and is ready to repeat the operation on the second tube when the first is again fired.

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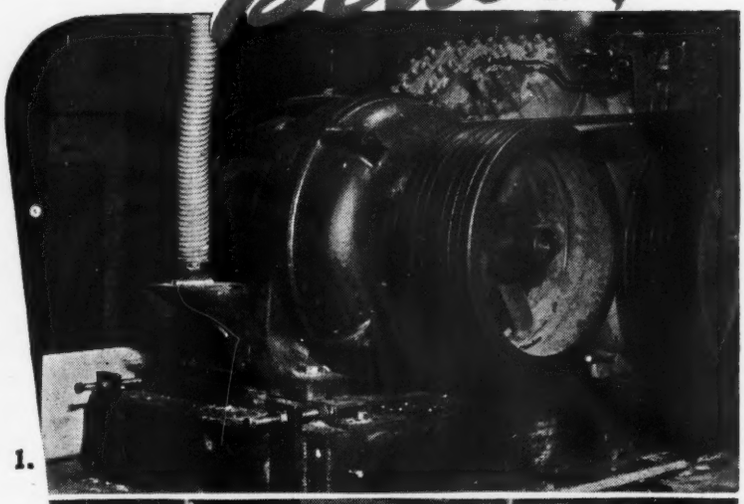

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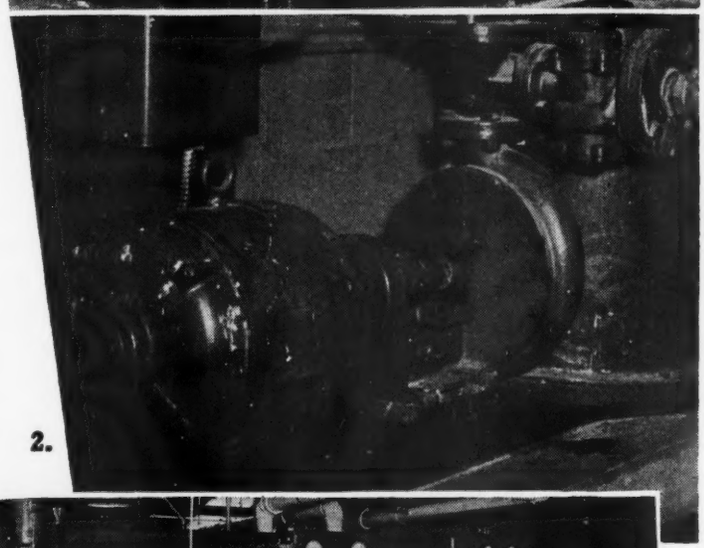

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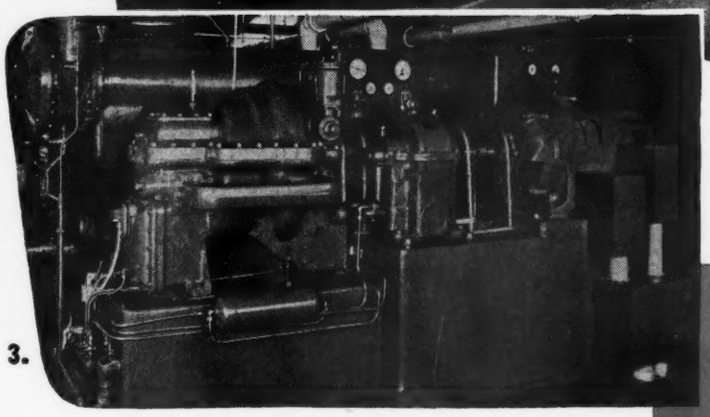

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2. Century 5 horsepower Type SC squirrel cage motor provides smooth quiet power for this vacuum feed pump.

3. Century 200 horsepower Type SR slip ring motor driving a compressor.

The high starting torque brings the compressor up to speed quickly and smoothly. The gear box increases the speed to 9,000 RPM.

There's a Century motor with the right electrical characteristics for all popular refrigeration, pumping, and air circulating applications.

Among their advantages are: the right starting torque, unusual freedom from mechanical and electrical vibration, rigid construction, adequate ventilation system, accurate machining and long life bearings.

Century motors for the heating, ventilating and air conditioning industry help to build customer satisfaction because they operate smoothly and quietly throughout their long life.

Century builds a wide range of motor types in sizes from 1/6 to 400 horsepower to assure top performance for every electric power application.

Specify Century for all your electric power requirements.

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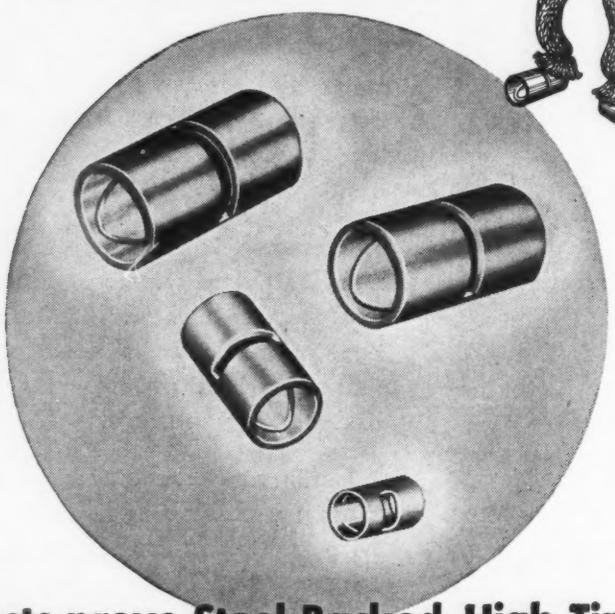
the guy who knows

ALL ABOUT
BEARINGS



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Pioneered by Wagner in 1927, steel-backed, high-tin, babbitt-lined bearings have proved superior both in laboratory tests and field performance. These steel-backed, high-tin, babbitt-lined bearings of prewar quality have been furnished for the past year. They withstand heavy pressure, resist seizure and shaft scoring and operate at low temperatures. That's why Wagner uses them exclusively in their famous fractional horsepower and smaller integral horsepower sleeve-bearing motors (203-505 frames).

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M548-3A

ELECTRICAL AND AUTOMOTIVE PRODUCTS

The primary current in the transformer primary, flowing alternately both ways to the middle, produces an alternating voltage in the secondary and permits an alternating current to flow in it.

However, because the load current is reflected back into the primary, the load must be known quite accurately for proper inverted design. There must always be sufficient capacitor effect (leading power factor) to permit commutation and deionization.

The timing of the grid firing, which determines the frequency of the a-c output may be obtained from the tubes themselves or from an external circuit. The value of the capacitor and resistor in the grid circuit will determine the firing point.

As the deionization time of a thyratron is comparatively long as expressed in microseconds, the output frequency of an inverter is limited to a few hundred cycles even with thyratrons designed for rapid deionization.—E.J.S.

A. TO QUESTION 283—The circuit given by E.J.K. is not quite correct as the cathodes of the tubes should be connected to the –Ve line.

Inversion may be started by making one of the grids positive. This will cause the tube to fire, thus lowering the potential across it. As one side of the tube grid condenser is connected to the first tube, the second grid will be raised positive and fire the second tube. This lowers the potential across the second tube. Now the voltage across the condenser between the two tubes cannot change instantly, so the plate of the first tube is forced negative and it stops firing. The process is then repeated, the condenser between the plates acting as a "commutator", turning off one tube when the other fires.

The frequency is controlled by varying the resistors in the cathode circuit, each one controlling the period of its own tube.—C.R.B.

Connectors for EMT

QUESTION 284—Several times electric metallic tubing services installed according to the code allowed rain water to escape through the main switch. It happened both before the wires were in and after the wires were in. The service head was in good shape. Why does this happen? *—H.S.*

SPOTLIGHTS A THOUSAND USES FOR

U·S·S Ampyrol

THE airplane beacon, the sign on the street, the X-ray in a doctor's office and the myriad lights of the city . . . all spotlight possible uses for Ampyrol wire and cable.

Ampyrol is versatile. It is chemically inert. Water doesn't harm it. Sun doesn't crack it. Oil doesn't rot it. That's why you can use it indoors or out.

Ampyrol is unaffected by acids, alkalis and many common solvents. It withstands ozone and does not support combustion. It has excellent aging qualities and remains flexible without cracking.

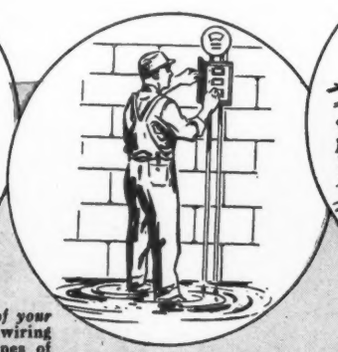
All these features make Ampyrol widely used for building wire, switchboards, motor leads, electronic devices and ordinary lighting fixtures.

The chief difference between U·S·S Ampyrol and other polyvinyl chloride insulations is in the method of manufacture. American Steel and Wire Company has developed special processes which assure better control at the mill. The resulting product is uniformly high in quality and physical characteristics.

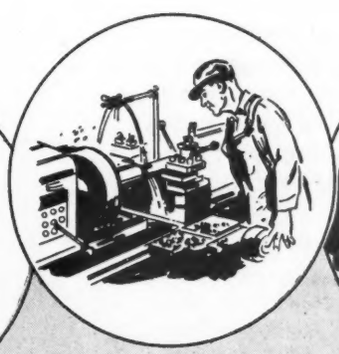
If you have a difficult wiring job, find out about U·S·S Ampyrol. Write for complete information on types and sizes available.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA STEEL COMPANY, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM
SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

Where you must increase the capacity of your lines without tearing up the conduit. Old wiring can often be replaced with Ampyrol lines of 50% to 100% greater capacity. The smooth, wax-like surface of Ampyrol makes it easy to pull through conduit.



Where moisture and mildew are a problem. Ampyrol does not absorb moisture — is unaffected by mildew.



Where wiring gets splashed with cutting oils, acids, alkalis, grease and coolants. No damage results for Ampyrol is impervious to all these agents.

Where weather or bright sunlight cracks ordinary cable. Ampyrol will give long service. It has excellent aging characteristics and remains flexible without cracking.

USS Ampyrol Wire and Cable

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Select the best, insist on Briegel All Steel Fittings, the only approved Indenter type connectors and couplings for thin wall conduit tubing. You will not only find that Briegel Indenter Fittings are easier and faster to use, but also make neater, stronger connections. Two Easy Squeezes and they're set. Start using Briegel Fittings today. Have more satisfied customers — more profits from each job.

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NEATER • FASTER • STRONGER • APPROVED •

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GALVA, ILLINOIS

A. TO QUESTION 284—I find that the connectors for electric metallic tubing are not water tight. I have found it to be a very good idea to paint around the connector with a weatherproof paint.—R.T.L.

A. TO QUESTION 284 — As H. S. stated that the service is installed according to code, this will rule out water working through the service head due to its being lower than the service wires and drip loops improperly made. Our next thought would then be that water would be dripping through the couplings or other fittings on the thin wall, since these are not considered water tight.

A good way to overcome conditions of this type would be to make a drain on the outside lower part of the service before it enters the building to the main switch, such as drilling a hole in the entrance fitting in such a way that moisture accumulating in the service conduit will drain away.

Another possibility on this is that there may be a big difference in temperature between the outside part of wiring and the inside part entering the main switch. This would account for a steady stream of water, and of course, the solution to this would be a sealing fitting at point of entrance.—J.M.M.

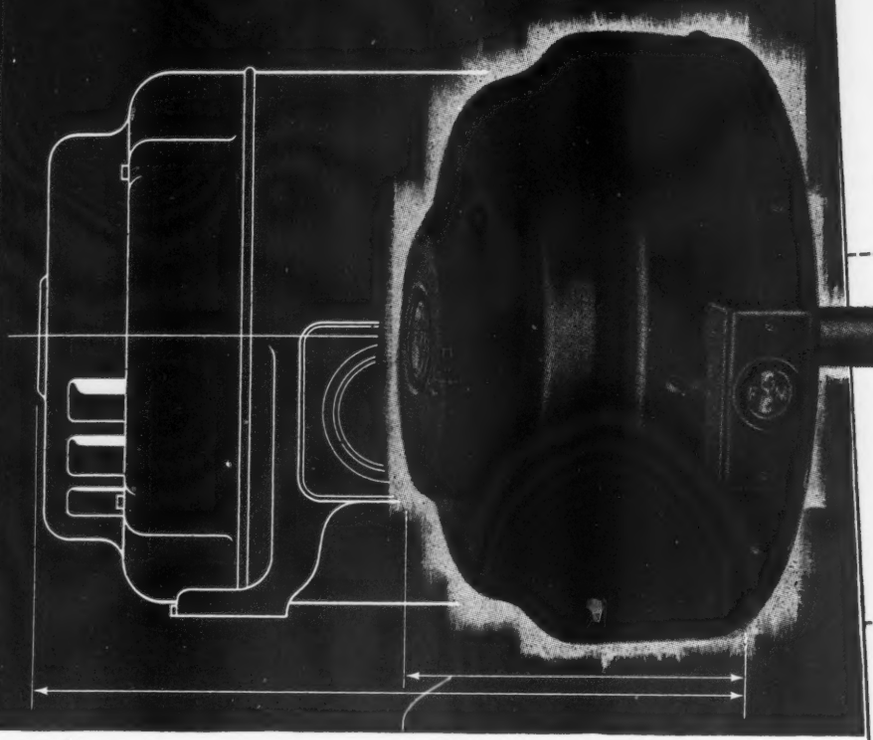
A. TO QUESTION 284—Metallic tubing or conduit service with service head in proper position should not allow rain water to enter in, although condensation will take place wherever metallic service enters from the outside to the inside of a building. To overcome this, a drop is formed before the main switch with a drain hole drilled in the metallic tubing or conduit. Condensation will even show up with the use of entrance cable in places where it leads from outside directly into a warm and damp room, as in a dairy barn wiring.—E.S.H.

Three Phase Induction Motors

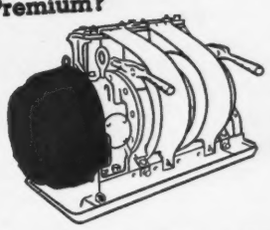
QUESTION 285—When several three-phase motors are to be installed on the same branch circuit, what is an easy way of predetermining their rotation?—T.B.B.

A. TO QUESTION 285 — The following method of predetermining the direction of rotation of several three-phase induction motors, before three-phase power is available, has been found easy and satisfactory.

Where can You use a lighter, shorter electric motor?



Where Floor Space is at a Premium?



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Where Headroom Counts?

. . . on **GEAR REDUCERS,** for instance

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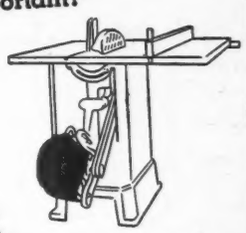

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FAIRBANKS-MORSE AXIAL AIR-GAP* MOTORS offer new possibilities in the application of electric power! These motors are radically advanced in design — over 30% lighter, 50% smaller than other motors of equal horsepower . . . yet they are 40-degree, standard wound squirrel-cage motors, with a range of application that is broader and more flexible than motors of conventional design. Their size, weight and design are new — their performance meets long-established Fairbanks-Morse high standards. Bulletin 2760 has full details . . . write Fairbanks, Morse & Co., Chicago 5, Ill.

**Air-Gap dimension is measured parallel to the axis of the shaft. Horizontal and vertical mountings; also, pivot base mountings. Polyphase squirrel cage and capacitor start, single phase types.*

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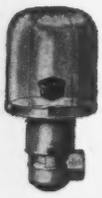

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- AUTOMATIC OILERS
- FUSE PULLERS

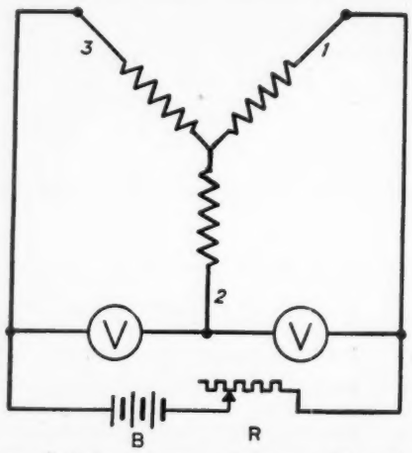
TRICO FUSE MFG. CO.
MILWAUKEE 12, WISCONSIN

The stator leads of the three-phase motor are connected as shown in the drawing. If the induction motor is of the slip-ring type, the rotor circuit is closed. Two low-reading voltmeters and a suitable resistor are connected as shown. The polarities of the battery terminals are immaterial.

When the rotor is at rest, the indications of the two voltmeters are constant. When the rotor is caused to rotate by hand or other mechanical means in a given direction, the deflection of one voltmeter will, in general, increase while the other one will decrease as the rotor starts to turn over. The stator terminal connected to the two voltmeters is marked "2". If the stator terminal to which the voltmeter with the decreasing indications is connected is marked "1", then the third stator terminal connected to the voltmeter with the increasing deflection will be marked "3". The phase rotation of the stator terminals thus marked is found to be 1-2-3 for the direction in which the rotor was revolved by external means.

If the rotor is turned in the opposite direction, the deflections of the two voltmeters will be reversed.

This phase rotation test for the stator leads of an induction motor may



be made with one voltmeter. The direction of the indicated deflection is interpreted in a similar way in determining direction of phase rotation.

Unfortunately, even a brief discussion of the theory involved in this relatively simple test is too lengthy to be discussed in this limited space.

Connections for determining direction of phase rotation of a three-phase induction motor without three-phase power supply.

Symbols:

V Low-reading voltmeter
B Storage battery of suitable voltage
R Adjustable rheostat of suitable resistance —R.G.C.

A. TO QUESTION 285 — Unfortunately, there is no easy

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IF YOU NEED IT FAST

Get it from your IWI Warehouse. IWI has stocks of everything you need, ready to ship the same day your order is received. You can save yourself time, worry and money—avoid unnecessary waiting and customer complaints — if you will just

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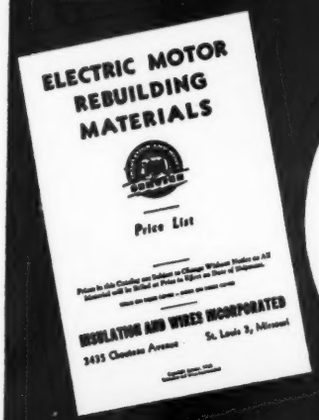

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For smooth, long-lasting performance and perfect fit there is nothing finer made than JOHNSON BRONZE SLEEVE BEARINGS. They are engineered to the highest standards in the industry — and precision produced by the most modern production methods so that every one is perfect.

You can always rely on JOHNSON BRONZE SLEEVE BEARINGS to exactly meet every requirement of any motor they're made to fit because — they are manufactured to the specifications of the motor maker — they are designed right and made of the right materials — they're precision machined to extremely close tolerances and inspected at every step of manufacture — they're cast of Alloy SAE 67 (copper 78%, tin 70%, lead 15%) for extra long wear without galling. For uniform quality and performance you can always depend on, make it your policy to specify only JOHNSON BRONZE SLEEVE BEARINGS.

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They have the perfect shape for the best possible protection against electrical and mechanical failures. They're formed to fit the motor slot perfectly — hold windings firmly in place — won't turn over in the slot — slip over both sides of the slot cell insulation — and permit windings to be placed closer to the top of the slot. U-WEDJ is made of the finest Fishpaper — is easy to handle and use — comes in standard 48-inch lengths or 250-foot bundles — and does a swell all-around job under the toughest service conditions.

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All brushes are equipped with standard shunts. Get our complete list of standard Superior grades which can be ordered by code number.

Size—Inches L.	W.	T.	Stock Numbers Grade 440	Grade 460
1½	1	¼	A00	B00
1½	1	⅜	A01	B01
1½	1	½	A02	B02
1½	1	⅝	A03	B03
1½	1¼	¼	A04	B04
1½	1¼	⅜	A05	B05
1½	1¼	½	A06	B06
1½	1¼	⅝	A07	B07
1½	1½	¼	A08	B08
1½	1½	⅜	A09	B09
1½	1½	½	A10	B10
1½	1½	⅝	A11	B11
2	1	⅜	A12	B12
2	1	½	A13	B13
2	1	⅝	A14	B14
2	1	¾	A15	B15
2	1¼	⅜	A16	B16
2	1¼	½	A17	B17
2	1¼	⅝	A18	B18
2	1¼	¾	A19	B19
2	1½	⅜	A20	B20
2	1½	½	A21	B21
2	1½	⅝	A22	B22
2	1½	¾	A23	B23

(NOTE: Grade 440 is Carbon Graphite) (NOTE: Grade 460 is Electrographitic.)

Size—Inches L.	W.	T.	Stock Numbers Grade 440	Grade 460
2	1¾	⅜	A24	B24
2	1¾	½	A25	B25
2	1¾	⅝	A26	B26
2	1¾	¾	A27	B27
2½	1	⅜	A28	B28
2½	1	½	A29	B29
2½	1	⅝	A30	B30
2½	1	¾	A31	B31
2½	1¼	⅜	A32	B32
2½	1¼	½	A33	B33
2½	1¼	⅝	A34	B34
2½	1¼	¾	A35	B35
2½	1½	⅜	A36	B36
2½	1½	½	A37	B37
2½	1½	⅝	A38	B38
2½	1½	¾	A39	B39
2½	1¾	⅜	A40	B40
2½	1¾	½	A41	B41
2½	1¾	⅝	A42	B42
2½	1¾	¾	A43	B43

(NOTE: Grade 440 is Carbon Graphite) (NOTE: Grade 460 is Electrographitic)

NOTE — ¼" and ⅜" thick brushes supplied with 3/16" open terminals — other ¼" open terminals.

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5000 WATTS D.C.

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Use fast-working electrical tools on any construction or maintenance job with this high capacity, portable, compact electric plant. Equipped with four-receptacle box for direct plug-in of tools or lights. Available with carrying frame, or dolly-mounted. Powered by Onan 10 HP, two-cylinder, 4-cycle, air-cooled engine. Shipped complete . . . ready to go!

NEW ONAN "CK" ELECTRIC PLANTS are available in 5000 watts D.C., 115 and 230 volts; 2000 and 3000 watts A.C. in all standard voltages.
COMPLETE ELECTRIC PLANT LINE INCLUDES: A.C.—350 to 35,000 watts in all standard voltages and frequencies. D.C.—600 to 15,000 watts, 115 and 230 volts. Battery Chargers—500 to 6,000 watts, 6, 12, 24, 32 and 115 volts.
ONAN AIR-COOLED ENGINES—CK: 2-cylinder opposed, 10 HP. BH: 2-cylinder opposed, 5½ HP. 1B: 1-cylinder, 3¼ HP.

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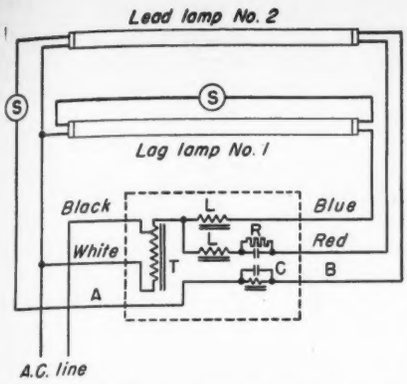
ONAN ELECTRIC PLANTS

way to predetermine rotation of three-phase motors. However, since they are all to be connected to the same branch circuit, and assuming the voltage to which they are to be connected is 440 volts, and dual voltage motors of the same make are used, and further assuming you can pick up the same phase wires on your branch circuit at the points to which they are to be connected, proceed as follows: Your motor leads for this potential will be marked and connected as follows: 1-2-3 will be leads to be connected to the same branch circuit wires, 5 & 8 connect together, 4 & 7 likewise and 6 & 9 to form a series Y connection for the higher voltage. Since these leads are brought out for a uniform polarity for a given make of motor, a trial connection on your branch circuit of one motor will give you a rotation test for the rest.—J.M.M.

Color Code for Ballast Heads

Q. *QUESTION 286—We have a two light fluorescent ballast with six leads—two red and one blue from one end, one black, one white and one yellow from the other end. The connection diagram is missing, and we would like to know the internal connections of the different leads. Is there a standard color code for ballast leads applicable to all makes?—J.J.L.*

A. TO QUESTION 286 — The internal connections of a 30- or 40-watt, 110-125-, 199-216-, or 220-250-volt, two-lamp ballast with built-in starting compensator are shown in the drawing. Smaller wattage two-lamp circuits do not require auto-transformers. The condenser with the shunt resistor in the lead lamp No. 2 serves a dual purpose. First, it improves the lamp supply circuit power factor to a value between 0.9 to 1. Second, it reduces the stroboscopic effect and flicker by causing a phase displacement in respect to the lag lamp No. 1 circuit which is predominantly inductive. The two current waves thus go through their zero values at different times. The choke coils are so designed as to have across them a voltage drop about equal to the voltage impressed across the lamp terminals. The starting compensator in series with the lead lamp No. 2 is used for changing the constant current characteristics of the lead circuit long enough to allow the current to rise and preheat the cathode. In lamps larger than 40-watt size, the normal arc current is sufficiently high to preheat the cathode



properly without the use of a starting compensator.

The color coding of four-lead, two-lamp ballast leads without built- in compensator has been standardized as indicated in the drawing. Manufacturers, however, do not seem to have agreed on the color coding of built-in compensator leads. The following are some of the lead color combinations used on built-in starting compensators:

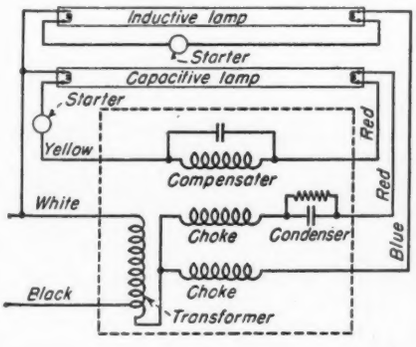
Lead A (On the black and white side)	Lead B (On the red and blue side)
Yellow	Red (as in present case)
Green-Yellow	Green-Yellow
Red	Red
Black	Black
Red-White	Red-Black

The internal connections of a 30- or 40-watt, 110-125-, 199-216, or 220-250-volt, two-lamp ballast with built-in starting compensator.

Symbols:

S—Starter
T—Auto-transformer
L—Choke coil
R—Resistor
C—Condenser
K—Starting compensator
A and B—Starting compensator terminals —R.G.C.

A. TO QUESTION 286—On 30 and 40 watt, two-lamp 110-125 volt ballasts with built-in compensators as described by J.J.L., I do believe that manufacturers follow the color code in their lead wires to simplify maintenance. These wires as will be noted are hooked as follows:



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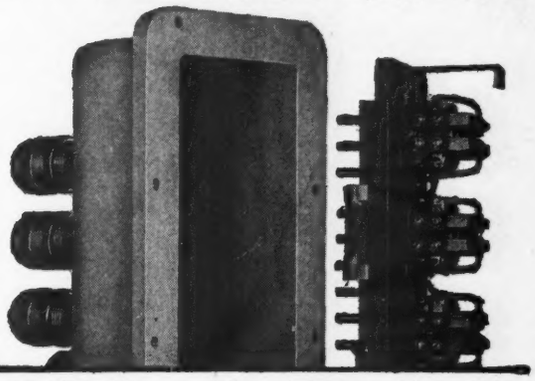
Complete Protection



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51

Silicone News

DC SILICONES

New Muscles for Motors

Ordinary motors refuse to be overworked. If a job is too tough, they quit and your machinery stands idle until a new motor is installed. Your only alternative to frequent motor failure used to be the installation of larger motors even though it might involve costly redesigning of the machine or the whole installation.

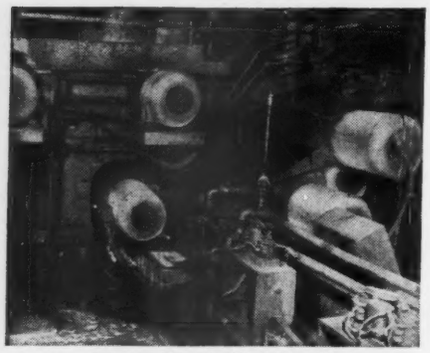

PHOTO COURTESY CARNEGIE-ILLINOIS STEEL CORPORATION

Silicone insulated motors still in service after 14 months of exposure to water, steam, high ambients and heavy overloads in steel mill strip coilers.

Now, there is an easier and far less expensive alternative. You can give your motors much greater overload capacity by having them rewound with Silicone Insulation. Here's an example from the Gary, Indiana plant of Carnegie-Illinois Steel Corporation. Coilers, driven by 7 motors, take red-hot steel strip from an 80 inch mill and roll it into coils while the strip is cooled with water.

These motors are exposed to water, steam, high ambient temperatures and overloads. After several failures, the bottom-most motors, which carry more than their share of the 12,000 pound load, were rewound with Dow Corning Silicone Insulation. Average life of Class B motors in those spots was 2 months. The silicone insulated motors were still in service after 14 months.

You can give motors about 10 times the life and 10 times the wet insulation resistance of Class B motors by having them rewound with Silicone Insulation according to the specifications given in data sheet No. K19-5.

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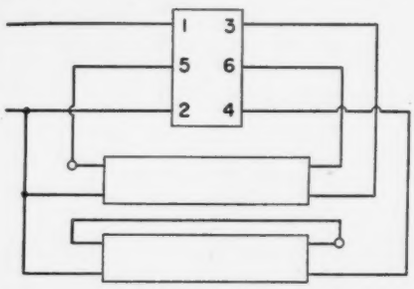
Dow Corning
FIRST IN SILICONES

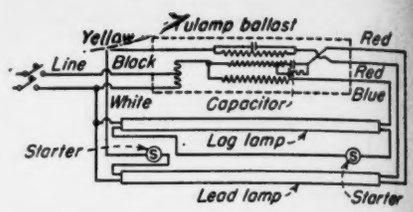
The black wire is hooked to one side of transformer and source, the white wire to other side of transformer and to each one of sockets on one side of lamp and line. The yellow wire comes from the compensator and ties in to one side of lamp starter socket. The other side of ballast has a blue wire that ties to one side of lamp and comes from one side of choke coil, the other side of choke coil and condenser comes out as a red wire and ties to the lamp, the other red wire ties to lamp and comes from the compensator as will be seen in the sketch.—D.J.S.

A. TO QUESTION 286—It is not advisable to depend on the colors, due to the reason that many times I found colors that did not agree with the sketch. By using a high resistance voltmeter tester, you locate 2 continuous leads 5 and 6, which are connected to the compensator. Now attach a 110 volt source in series with a 110 volt, 60 watt lamp. Test with a voltmeter to see if the other 4 leads are continuous. Test with the 60 watt lamp between the 2 leads which will



light up the 60 watt lamp. These 2 leads are called 3 and 4. Connect the other 2 leads in series with the 60 watt lamp. Test with a high resistance voltmeter between 3 and 1 or 2 to see which gives about 200 volts, which is the open circuit voltage between the opposite sockets. If 1 light is slow in starting, then use the compensator for that lamp.—H.S.

A. TO QUESTION 286—This is a Tulamp ballast. They use the "split-phase" principle with one of the lamps ballasted by inductive reactance only and the other by inductive and capacitive in series, and result in an over-all power factor 95% or better. Tulamp ballasts for 118-volts operation of 30, 40 or 100-watt lamps consist of an autotransformer winding and two reactor windings on a single core; but for 15 to 40-watt lamps inclusive require a starting compensator, an inductive winding connected in series with the leading circuit's starter, to insure satisfactory life and lumen maintenance and to provide more positive starting conditions at low temperatures and voltage frequently encountered. Most ballasts now have the compensator in the ballast itself. When the ballast does not have the compensator they should have it wired in as a separate element; if this was not used, unsatisfactory lamp performance is likely to be encountered, especially if the lamps are started frequently.



I have never encountered any color code for fluorescent lights, but here is a drawing that may explain the above.—H.R.G.

Can you ANSWER these QUESTIONS?

QUESTION J13—I was recently called to service a 500 hp. mine hoist motor. The pedestal bearing surface was found to be pitted due to a current flowing from the motor shaft to the bearing. This is a 2200 volt wound rotor motor, 60 cycle, with the star point of the rotor winding grounded to the shaft. Is it possible for this current to be induced into the shaft from the stator or is it caused by a leak to ground somewhere in the rotor resistance circuit?—J.H.S.

QUESTION K13—Due to rare but at the same time annoying power interruptions of two to ten seconds duration, usually at night, we have an important life test motor dropping out. Due to operation procedure, it is important that this motor does not restart if power failure is longer than 30 seconds; however, if the interruption is less, it will do no harm if the motor stays on the line. An ordinary 3 phase 220 volt 20 hp. magnetic starter with start-stop button is used. Is it possible to rewind the holding coil of the starter or incorporate a relay in the circuit so the starter will hold for 30 seconds after the power is off? The stop button must continue to drop out of the contactor immediately when used, also without interfering with the overload relays.—L.R.D.

QUESTION L13—We would like to know the internal circuits for two lamp fluorescent fixtures to be operated on direct current. What are the basic differences between these and those used on a-c?—H.S.

PLEASE SEND IN YOUR ANSWERS BY AUGUST 15

Answered by
F. N. M. SQUIRES and GLENN ROWELL
Chief Inspector
New York Board of Fire Underwriters
New York, N. Y.
Electrical Engineer
Fire Underwriters Inspection Bureau
Minneapolis, Minn.

Questions on the Code

Bushings on Connectors

Q. *When electric metallic tubing (thin wall conduit) is terminated in a box, is it required to place a bushing on the connector in addition to the locknut or, is it not true that the connector approved for use with electrical metallic tubing is bushed by the manufacturer and a locknut is sufficient?*

We would appreciate any advice that you have on the subject as we cannot find any ruling in the Code book requiring a bushing.—P.S.F.

A. Electrical metallic tubing not being threaded for locknuts and bushings, is not connected to boxes by these devices, but requires the use of connectors approved for this material.

These connectors are required to have smoothly rounded edges to protect the connectors from mechanical injury and therefore do not require the use of bushings in addition to the locknut except wires of No. 4 or larger which are deflected more than 30 degrees. This requirement is found in Section 3736. Para. V.—F.N.M.S.

Service Equipment

Q. *Section 2351 of the Code requires that the service switch be located at a readily accessible point nearest to the entrance of the conductors, either inside or outside the building wall. Now does this mean that we cannot mount the meter on the line side unless the meter is outside the building and if the service wires enter the wall at a point used as a coal bin must the service equipment be placed in the coal bin?*—M.R.

A. The meter may be placed on the line side of the service equipment and also inside the building. Under Section 2352 you will find permission to locate the meter on the line side of the disconnecting means and under Section 2375 you will find the following rule:

"The meter may be placed on the supply side of the overcurrent device for alternating current supply not in excess of 300 volts between conductors, and provided the conductors between the meter and service equipment are installed by any of the methods specified in Section 2331 for service conductors."

As to the location of the service equipment, the section quoted in your question states that "service equipment shall be located at a readily accessible point nearest to the entrance of the conductors", so inasmuch as the coal bin when full of coal could not be considered as a readily accessible location, the service equipment should not be located therein. If it is impractical to bring the service conductors through the building wall at some other point, the service raceway should extend through the coal bin to the first readily accessible point.—G.R.

Service Cable

Q. *Our company is attempting to set up specifications for service entrances in towns where no inspecting authority exists, a situation rather common. We are uncertain in regard to the matter of service entrance cable.*

Article 3381 says:—"Unarmored cable shall be installed in accordance with the applicable provisions of Article 336." Article 336 sets up standard of installation for non-metallic sheathed cable. In Article 3362, 2nd sentence, the following statement is made: "Non-metallic sheathed cable shall not be used as service entrance cable; . . .".

We also notice in scanning the 1940 Code, that the last statement "Non-metallic sheathed cable shall not be used as service entrance cable . . .", is not present.

Is it the intent of the Code to eliminate use of unarmored cable, Type SE, for the use in service entrances, or is the statement in Article 3362 not considered an applicable provision?—F.M.

A. Service entrance cable was designed to be used for service entrance work but Sections 3381, 3382 and 3383, govern its use for interior wiring. In other words, service entrance cable may be used for interior wiring if Sections 3381 and 3382 are complied with but the Section 3362 states that non-metallic sheathed cable cannot be used for service entrance work. The presence of this rule in the 1947 Code while it was not in the 1940 Code, is to clear up some misunderstanding about their uses.

Labelled "SE" cable may be used for service entrance work above ground if not subject to mechanical injury.—F.N.M.S.

Lighting Fixtures

Q. *On a certain hospital job the architect specified explosion-proof wall switches for ceiling light control in both the delivery and operating rooms. He also specified that the overhead light units be of the type that operate on a trolley, street car style with hot tracks. Does this make sense?*—A.H.

A. No, it does not make sense provided the surgical lamp is to be used in an operating room in which combustible gaseous anesthetics are to be used. The N.E. Code under article 500 would require that all electrical equipment in such areas be approved for use in a Class I Group C location. There is, however, an exception made to this rule for lighting fixtures including surgical lamps which are seven feet or more above the floor provided the room is equipped with a ventilating system which will assure at least 12 changes of air per hour. The only manner of assuring continued operation of such a ventilating system is to provide interlocking electrical con-

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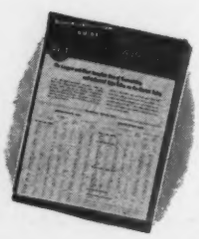

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trols. This exception, while not contained in the N. E. Code as yet, is practical and will be found in a pamphlet entitled "Combustible Anesthetics in Hospital Operating Rooms" published by the National Fire Protection Association.—G.R.

Feeder Switch

Q. *A residence has a small range and a 4 circuit fuse box, 3 No. 6 wires furnish the service through a 60 amp. disconnect; a 30 amp. disconnect is installed for the fuse panel. Is it proper to connect this 30 amp. switch to the line side of the 60 amp. switch or should it be on the load side?* —C.H.C.

A. Inasmuch as there are 4 fused circuits, the 30 amp. disconnect cannot serve as a service switch. This is governed by Rule 2357. Therefore the 30 amp. disconnect should be connected to the load side of the 60 amp. service switch and there it becomes a feeder switch.—F.N.M.S.

Running Protection

Q. *We plan to install a group of small metalworking machines powered by fractional horsepower motors, the largest being 1/3 hp. 110 volts single phase. These motors will all be manually controlled. Will the Code require separate running protection for each motor or will the fuses on the circuits supplying the motors be acceptable for both circuit and motor protection?*—B.A.

A. Section 4322b contains the answer to your question. This paragraph reads as follows: "Any motor of one horsepower or less which is manually started and which is within sight from the starter location, shall be considered as protected against overcurrent by the overcurrent device protecting the conductors of the branch circuit. This branch circuit overcurrent device shall not be larger than that specified in Table 20 Chapter 10, except that any such motor may be used at 125 volts or less on a branch circuit protected at 20 amperes. Any such motor which is out of sight from the starter location shall be protected as specified in paragraph c for automatically started motors."

Therefore as long as the motors are

1/3 hp. or less and are within sight of their starter locations, the N.E. Code will not require individual running protection. It should be remembered that this code is a set of minimum requirements and therefore while individual protection is not actually required, it would be most practical from an engineering point of view to provide such protection especially where more than a single motor is served by a common circuit.—G.R.

Heating of Fuses

Q. *Will you please answer the following questions—Why does a 15 amp. fuse plug with only 10 amp. load, heat the plug?*

Why does a 60 amp.-250 volt cartridge fuse with only a 30 amp. load, heat up?—R.W.C.

A. There are many factors which contribute to the undue overheating of fuses, which are operating under loads of less than the capacities of fuses; all of which would have to be known before guesses could be hazarded.

One of the most prevalent causes is poor contacts. This might be caused by loose fitting of current-carrying parts of dirty or corroded contact surfaces. High ambient temperatures, also contribute to overheating.

Another cause is continuous operation.

It must be kept in mind that as soon as current flows through a fuse, heat is developed, but of course, with only a half load going through it, a fuse should not get really "hot".

One prevalent reason for overheating is that some fuses will become loosened in their fuse holders, through vibration. This looseness will often cause overheating.

Another contributing factor prevalent with plug fuses is backing a fuse out of the fuse holder under load. This develops pitting of the contact which makes a poor contact. When the fuses are put in again of course this helps develop heat.

Many pieces of electrical equipment were not designed for "continuous operation" but were designed to carry a normal load for the average time they normally would be in use and they would have the opportunity of cooling off before the next use period. When, however, they were called on for continuous or even "around the clock operation" they had no cooling off periods and would accumulate quite a lot of heat.—F.N.M.S.

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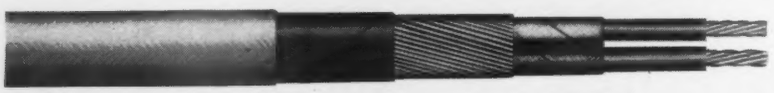

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Type SE, Style U, unarmored, with concentrically wound bare neutral. Gray weatherproof braid — flame retardant and inconspicuous.

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Garage Wiring

Q. *The existing wiring in a transport truck garage has been condemned and we have been asked to do the rewiring job. This building houses a number of large tank trucks used for hauling various petroleum products and while they will normally be empty when stored within the garage, it is possible on occasion to have one or more filled tank trucks stored there. In addition, all repairs and maintenance necessary will also be made in this garage. Now may we wire this building as we would any other garage, or will it require special wiring?*—M.M.G.

A. If any of these tank trucks will be used to haul gasoline or any other combustible liquid having a flash point at or below the ambient temperature common to this garage, it should be wired as required by Article 500 for a Class 1 Division 2 location. You will find this provision under Section 5156 of the N. E. Code. Whether or not the tanks are full or empty should make no difference in the treatment used as the so-called empty tanks are probably the most dangerous.—G.R.

Size of Neutral

Q. *On a 4 wire 120-208 volt 3 phase system; if you had an active load of 300 amperes per phase, you would use 500,000 C M cable for the service. What size should the neutral be? I would say it should be 70 percent of the carrying capacity of the 500,000 C M cable or 250,000 C M according to Article 230, Section 2304, Paragraph A, of the 1947 Code.*—L.R.T.

A. The 70 percent demand factor for the neutral conductor is not to be applied to the whole carrying capacity of the wire. The last portion of Section 2203 g states that a "further demand-factor of 70 percent may be applied to that portion of the unbalanced load in excess of 200 amperes. Therefore if the unbalanced load per phase is 300 amperes; the computation is as follows:

200 amps. at 100 percent equals 200 amps.
300 amps. minus 200 amps. or 100 amps. at 70 percent equals 70 amps.
Total Neutral Load .....270 amps."
200 amps. requires 400,000 CM Conductors. —F.N.M.S.

Colored Conductor

Q. *We have just been advised that we must replace a green colored insulated conductor with one of some other color due to the use to which it was put. On this job we wanted to identify the various circuits contained within a common raceway and had a bit of trouble finding enough different colored insulation. The motors supplied were both three phase and were both grounded via the conduit raceway so a separate grounding conductor was not necessary. Were we violating the Code in using a green colored conductor for a current carrying wire?*—J.A.

A. No. If there is no need for an equipment grounding conductor within the conduit the N. E. Code would not prohibit the use of an insulated conductor having a green exterior finish as one of the ungrounded conductors. Section 2557 states that a conductor used as a grounding conductor for fixed equipment if insulated shall be finished to show a green color, but it does not state that the color green must be reserved for such use. Then under Section 94003 you will find a fine print note that reads as follows: "This shall not be construed as prohibiting the use of a conductor having a green finish as an ungrounded circuit conductor in cords having no conductor used as a grounding conductor."—G.R.

Grounding a Motor

Q. *I have been asked to ground the frame of an electric motor that is located on the second floor quite some distance from the service equipment which is located in the basement. Does the Code require a separate grounding wire from the motor to the neutral block in the service equipment, or may I attach this grounding wire to the nearest water pipe?*—D.L.

A. If the neutral terminal block of the service equipment is grounded to the water service pipe entering the building, the use of the cold water pipe nearest the motor would be permissible provided a bonding jumper was placed about the water meter. Section 2554 of the N. E. Code reads as follows: "Where the alternating-current system is connected to a grounding electrode in or at a building as specified in Sections 2523 and 2524, the same electrode shall be used to ground wire enclosures and equipment in or on that building.—G.R.

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- **Spring-action keeps lamps well centered... assures positive floating contact.**

RESULT:

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The **DAY-LINE** Heavy-duty industrial fluorescent fixtures are designed for two and three 40-watt and two 85-watt lamps. Sturdy, porcelain enameled reflectors... truss-type channel construction... unit or continuous installations. The 40-watt fixtures are equipped with the new TURRET Sockets and open or closed end reflectors.
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Painting, washing and storage areas have been adequately lighted with explosion-proof lighting units, and wired in accordance with National Electrical Code regulations for hazardous locations. Thus, lighting and wiring provide maximum safety to handlers of lubricants, fuels and paint, and car washers.

Property protection against prowlers is provided through planned outside lighting.

Fluorescent industrial reflector units provide high levels of lighting in the entrance ramps, car storage and mechanical repair areas. Both 2/40-watt and 3/40-watt units are used.

Electrical facilities installed for purposes of safety and conveniences are many. Photoelectric controls operate all vehicle doors, which remain open only during light-beam interception. A time delay switch turns on current for door-closing.

An alarm bell set off by light-beam interception warns all other approaching vehicles that the doorway is in use. Limit switches automatically turn off unit heaters when doors open, reducing the intake of cold air by these heaters to provide minimum heat loss.

Motor-operated air pumps transfer oil to lubricating stations. Gasoline is pumped from outside, buried storage by electric pumps that start automatically in the outside pump house when hoses are lifted at the in-building dis-

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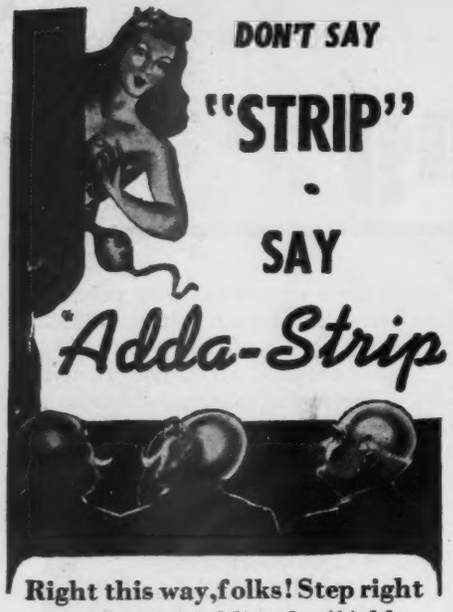
Explosion-proof lighting units and wiring are used in fuel, lubricant and paint storage areas of East Ohio Gas Company garage, Cleveland, Ohio.

High level lighting from explosion-proof units and wiring protect car washers in washing area of garage.



Right this way, folks! Step right up and meet Addie, the "Adda-Strip" girl. Look for her at leading wholesalers. And remember don't say "strip", say "Adda-Strip". It's the password that saves you money in the long run ... and the longer the run the bigger the saving. 18 inches or 18 miles, Adda-Strip's unique construction features and superlative, precision-built quality add up to quick, inexpensive installations.

*ADDA-STRIP T. M. REG. U. S. NO. 394,728 U. S. PATENT NO. 2,434,781

No. 8000 Adda-Strip, 18" to 8 ft. lengths Completely wired and assembled including wire leads for splicing and feed.

No. X8000 strip at lower prices. Small end boxes, no wire leads.

FAST, ONE-MAN INSTALLATION

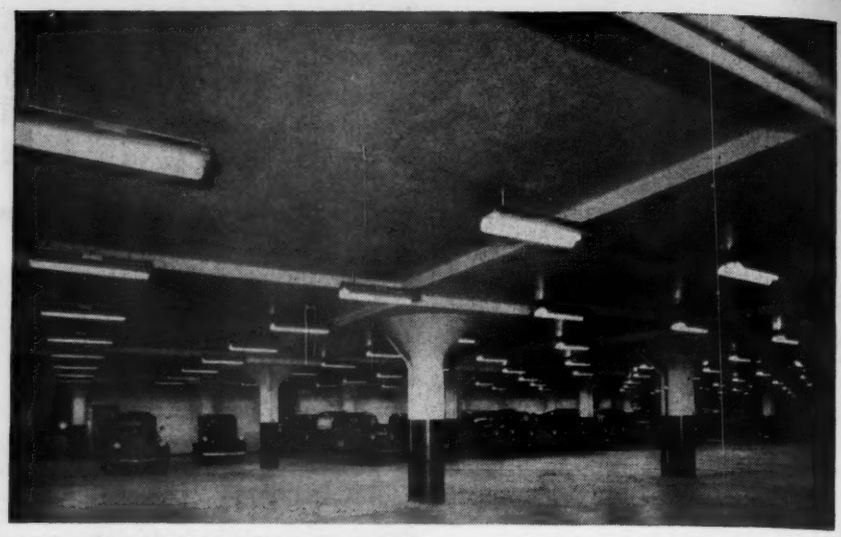
- Wired complete with ballasts, starters, sockets and lead wires.
- Covers snap on—hold without screws.
- Embossed screw-holes automatically line up ends and couplings.
- 8 ft. units save handling and splicing on continuous runs.

Adda-Strip is the most complete line, including single and double row for fluorescent or slimline and vest pocket strip for confined areas. Accessories include reflectors, hinged louver shields, louver and plastic shielding combinations.

GARCY — America's leading manufacturer of strip lighting

GARDEN CITY PLATING & MFG. CO.
1750 North Ashland Avenue
CHICAGO 22, ILLINOIS

1898 - 50 YEARS OF LEADERSHIP - 1948



Standard industrial 2/40-watt fluorescent units provide high level lighting in car storage area, providing added safety for drivers.

pensers. Similar pumps unload bulk gasoline going into storage.

Mobile carbon-dioxide dispensing units for fire fighting, one to each floor, are plugged into wall receptacles during non-use to operate refrigeration equipment that keeps dry ice at storage temperature.

When no employee is using the basement record department, temperature is automatically maintained at 60 degrees.

However, the first wall light switch flicked when this area is entered trips a transfer relay that puts unit heaters on the 75-degree range.

Redecoration Aids Classroom Lighting

Successful lighting in the school classroom depends on more than the installation of proper lighting equipment. Correct type lighting units are important. But equally important are color and finishes of ceilings, side walls, desks and furniture, floors, doors, windows and woodwork trim.

A classroom in the Pass-a-Grille, Florida elementary school illustrates the importance of both lighting and decoration. This classroom houses the first and second grades. It has been both relighted and redecorated, under the sponsorship of the Pass-a-Grille Lions Club.

Classroom in Pass-a-Grille, Florida, elementary school has been relighted and redecorated. New intensity ranges from 38 to 42 footcandles and brightness contrasts are within comfortable limits.

Originally, the lighting consisted of two totally indirect luminaires of the combination incandescent-mercury vapor lamp type. Lighting intensity varied from one to eight footcandles. This low intensity resulted from poor light utilization, including poor reflection factors for ceilings, side walls and floors, and dark glossy finish on desk tops.

The ceiling, walls and woodwork were repainted in a flat finish, soft aqua-green in color, which has a high reflection value. Matching venetian blinds were installed at the windows. Desk tops and floors were sanded and refinished in a natural wood shade.

A new lighting system was also installed. It consists of three continuous rows of luminous indirect Wakefield "Star" units, seven units per row. Each unit is equipped with two 40-watt white fluorescent lamps. This new lighting system provides an even, glareless illumination of 38 to 42 footcandles. Brightness-contrasts are within the limits recommended for comfort and maximum ease of seeing.

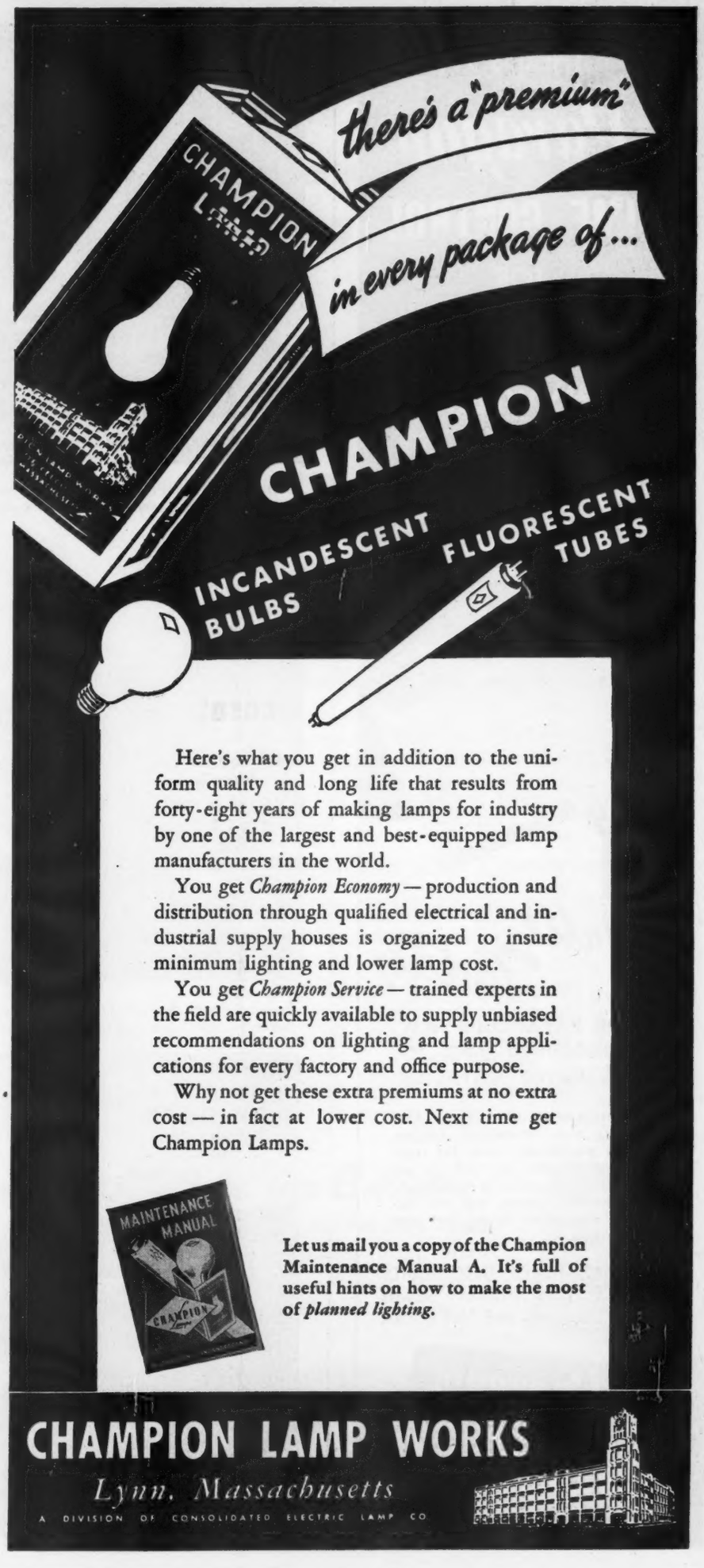
The reaction of the pupils to the new lighting and new decoration has been extremely gratifying. According to their teacher, they voluntarily keep hands and feet away from the new pastel finished walls and woodwork, and a definite improvement has been shown in interest in their work. Results on the whole were so favorable that the Pass-a-Grille Lions have already begun sponsoring new activities to raise money for the modernization of another room, and intend eventually to complete all four rooms in this small grade school.

Plans and specifications for both lighting and decorating were made by the commercial development department of the Florida Power Corporation, St. Petersburg, Florida.

Troffers Light Laboratory Offices

Fluorescent troffers were used extensively for lighting the offices, executive suites and library of the new geophysical laboratory building designed and built by the Austin Company for the Shell Oil Company in Houston, Texas. Cold cathode coves and coffers provide decorative and functional illumination in other non-laboratory areas.

Maintained intensities of more than 50 footcandles are provided in office areas by recessed two-lamp Miller fluorescent fixtures mounted either in continuous rows (on 5-ft. centers), or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in every package of...
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INCANDESCENT BULBS
FLUORESCENT TUBES
Here's what you get in addition to the uniform quality and long life that results from forty-eight years of making lamps for industry by one of the largest and best-equipped lamp manufacturers in the world.
You get Champion Economy — production and distribution through qualified electrical and industrial supply houses is organized to insure minimum lighting and lower lamp cost.
You get Champion Service — trained experts in the field are quickly available to supply unbiased recommendations on lighting and lamp applications for every factory and office purpose.
Why not get these extra premiums at no extra cost — in fact at lower cost. Next time get Champion Lamps.
MAINTENANCE MANUAL
Let us mail you a copy of the Champion Maintenance Manual A. It's full of useful hints on how to make the most of planned lighting.
CHAMPION LAMP WORKS
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A DIVISION OF CONSOLIDATED ELECTRIC LAMP CO.

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Paragon
ELECTRIC COMPANY

1614 TWELFTH ST.
TWO RIVERS, WISCONSIN

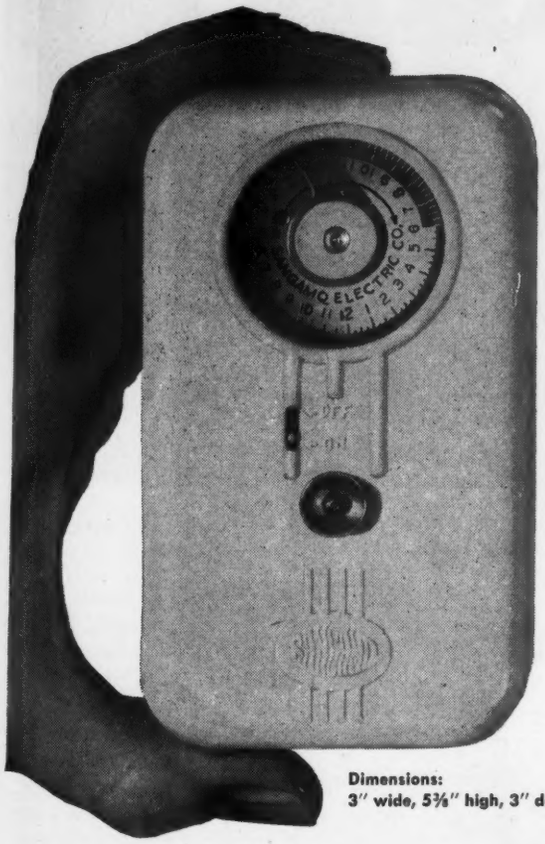
Continuous rows of recessed fluorescent troffers with eggcrate louvers provide better than 50 footcandles of illumination in general office areas.

Panel library has glass-enclosed recessed fluorescent fixtures in rectangular pattern. Exclusive offices and conference rooms have similar paneled walls.

Continuous cold cathode cove and indirect drum-type center units illuminate combination cafeteria-auditorium.

IT SELLS ON SIGHT...

The New Sangamo *Type S* Time Switch



Dimensions:
3" wide, 5⅜" high, 3" deep.

LOW PRICE • HIGH QUALITY

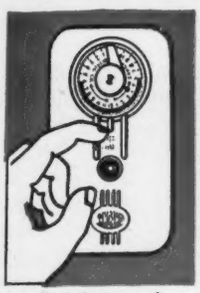
You wouldn't expect to find a time switch of such precise workmanship selling at such an unusually low price! Neither do your customers . . . *until you show them.*

Sangamo Type S Time Switches open a new field of time switch applications. High quality at low cost permits the economical convenience of automatic control in many installations where cost was formerly a prohibitive factor.

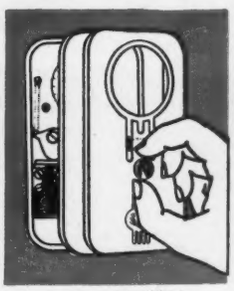
This switch is just what your trade has been wanting! Low in price, small in size, this precision-built, accurate time switch means quick sales—and ready profits for you.

Ask to see the Sangamo Type S Time Switch. Its exacting workmanship will surprise you. These switches are available for immediate delivery at your electrical wholesaler.

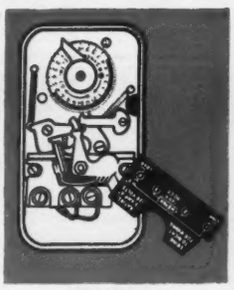
Features like these are typical of Sangamo Quality Construction



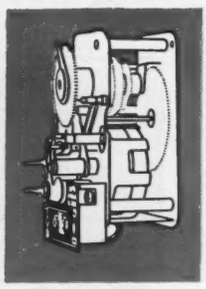
Outside Manual Operation



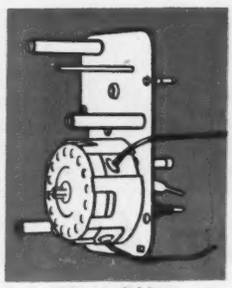
Cover Readily Removed



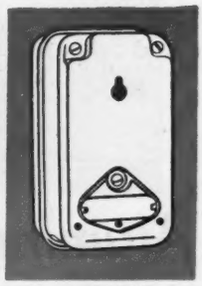
Dead Front Safety Design



Precision Machined Gears



Dependable Low-Speed Motor



Simple Switchbox Mounting

LIST PRICE

$12.45 (Trade Discounts Apply)

Available in Brown or Ivory cases. Type S has one "on" and one "off" operation; Type SR has two "on" and two "off" operations. Ivory case and Type SR are priced slightly higher.

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Get acquainted with the full story—specifications—installations—applications and prices. Write for Bulletin 1050A. It gives complete details.

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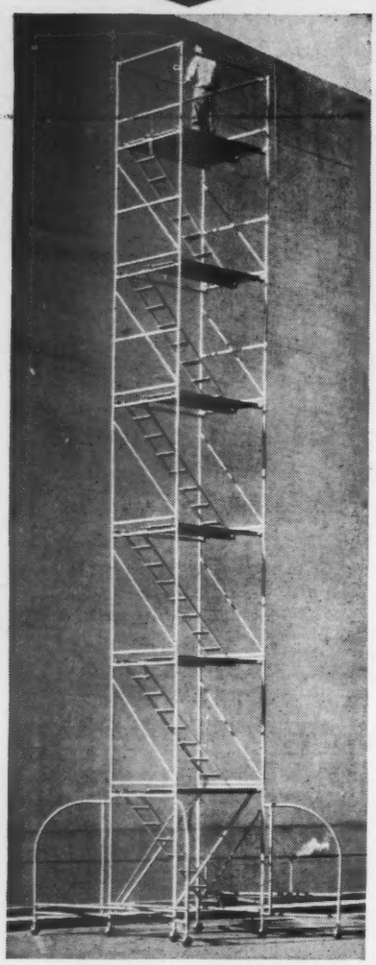

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Yours! . . . this sensational cost-cutting scaffold advancement. A 7-foot, single section unit requires only 1 minute to erect; a 45-foot multiple unit only 15 minutes. Rolled easily from position to position throughout the job. Stronger than structural steel yet one-third the weight. Safety-tread stairway completely within the structure. No wrenches, wing nuts, bolts, loose parts. Each section folds flat.

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UP-RIGHT SCAFFOLDS
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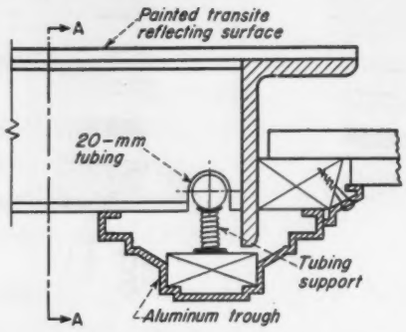
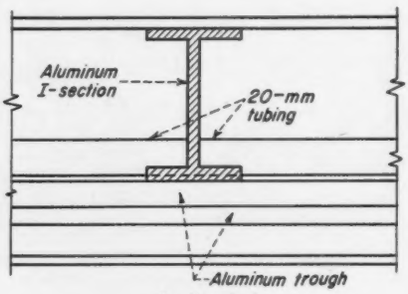
BERKELEY, CALIFORNIA
Offices in All Principal Cities

Unique lobby lighting combines aluminum I-beam cross pieces and inverted aluminum cold cathode troughs to produce coffered ceiling effect.





Section A-A

Construction details of the unique indirect cold cathode lighting "fixture" in the lobby.

square, rectangular or other patterns depending upon architectural and specific work requirements. Eggcrate louvers shield the lamps in the general office areas; diffusing glass panels in the library and executive office suites which have cold cathode cove lighting.

Soft, cold cathode, indirect illumination for the combination cafeteria-auditorium is produced by continuous 12,000-volt tubing concealed in a large cove around the perimeter of the room and in drum-shaped center fixtures. Interior illumination of corrugated structural glass pilaster panels provides an added decorative touch. Incandescent lamp reflectors are mounted in the base of each column. The cafeteria area can be quickly transformed into an auditorium by simply lowering an overhead door which seals off the service area.

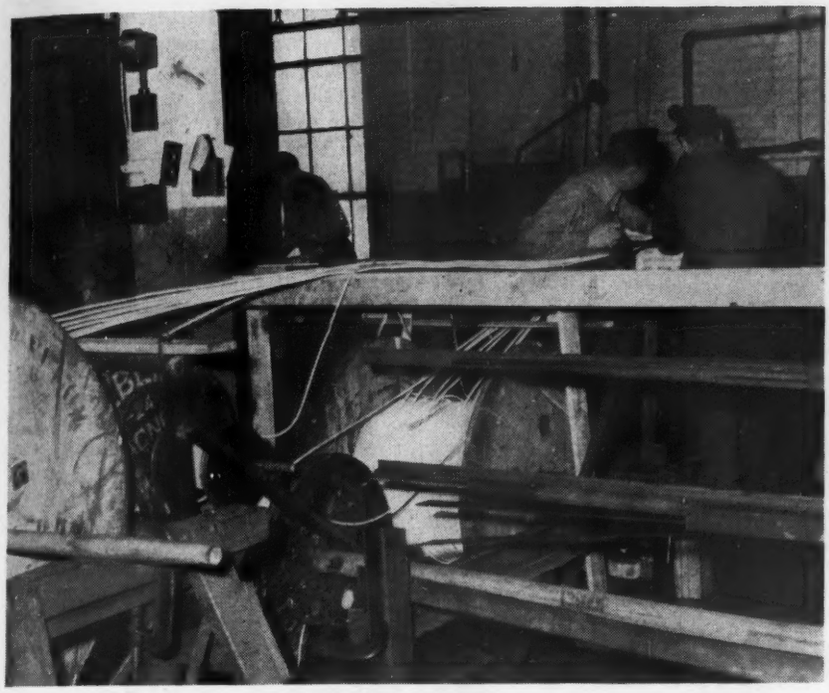
Walls of the general office areas are painted soft blue-gray and gray-green; those of the library, conference rooms and executive suite are paneled in walnut. Ceilings are finished with metal acoustic tile.

An interesting coffered ceiling effect is produced by a unique application of indirect lighting in the main lobby. The "fixture" consists of a series of 4-inch aluminum I-beams set crosswise (at about 4-ft. intervals) in a ceiling coffer. These beams support four continuous rows of 20 millimeter, 3500° white, cold cathode tubing (100 milliamps, 12,000-volts) mounted in inverted, extruded aluminum troughs. The painted transite reflecting surface of the coffer combines with the polished Texas fossil limestone walls to provide adequate, soft lobby illumination.

By combining incandescent and fluorescent lighting sources and by utilizing eggcrate louvres, diffusing glass panels, indirect coves and special reflectors, lighting becomes an integral part of the overall architectural treatment and is a definite asset in producing a decorative yet functional illumination plan in the Shell geophysical laboratory building. In this completely modern structure, the utilization of cold cathode illumination is particularly advantageous in considering the air conditioning.

Motor Shops

Rewinding Large Transformer Coils



De-reeling setup for winding 16-conductor turns of secondary winding. Two reels have seven parallel conductors each; two, single conductors. Small spools contain cotton rope spacer.

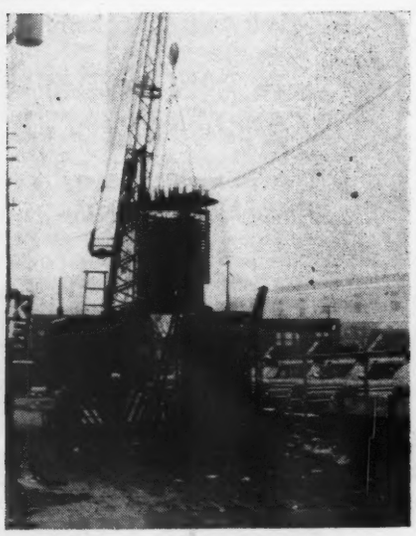
Two-man crew stacks and binds secondary turns, (double tier of eight conductors each) as they are wound on form. Here the second layer has just been started.

In the field of electrical equipment repair Spaulding Electric Company, Detroit motor repair shop, is equipped to handle anything from fractionals to large motors; from solenoid coils to seven-ton transformers.

Recent experience with an 800 kva. electric furnace transformer presents ample evidence of their ingenuity. The 14,000 pound, 4800/230-volt 3-phase, water-cooled, oil-immersed unit was 10 feet high, too tall to permit removal of the windings in the shop. So Spaulding hired a crane to lift out the windings in the yard where clearances were unlimited.

After the core was brought into the shop, rewinding presented a problem. The primary windings required 540 turns (including 116 turns of overwinding) of two No. 9 square conductors in parallel. The secondary windings took 10 turns (two layers, five turns per layer) of 16 No. 2 square conductors in parallel.

Biggest headache was the reel setup for winding the secondaries which consisted of a double tier of eight conductors each. Spaulding shop foreman George Glenning confined his de-reeling scheme to four reels for conductors and two spools for cotton rope. Two of the wire reels contained seven No. 2 square conductors each, the other two had single conductors. Each small



Crane lifts 3½-ton water-cooled core of 800 kva. furnace transformer from tank in Spaulding yard.

Immediate Delivery
FROM STOCK

Power Circuit Transformers

THE most economical way of providing low voltage circuits for the lighting and operating of machine tools is to run a branch line from the power line, using a transformer to step down the voltage.

Dongan Transformers are being used for this purpose in industrial plants throughout the nation, reducing installation time and also conserving critical materials.

DONGAN ELECTRIC MFG. CO.

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The Dongan Line
Since Nineteen-Nine

DONGAN
TRANSFORMERS

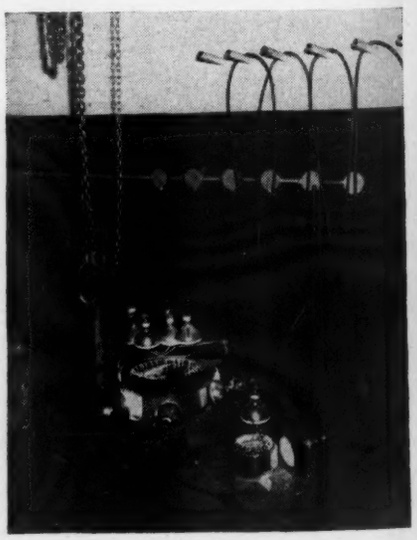
spool contained ¼-inch cotton rope used as a spacer between winding turns.

The 16 conductors were fed through a double tension block (8 top and 8 bottom) with pressure adjusted by means of a C-clamp. Turns were built-up as they were wound on the wood form by a two-man crew. One mechanic aligned the 16 conductors in a double tier while the second one tightly spiralled cotton tape around the group. The double cotton rope spacer was similarly "stacked" and taped. From here on, normal transformer winding techniques were used.

Another innovation, a winding temperature rise alarm, was added at the owner's request. Spaulding installed a "Thermohm" temperature indicator between the two layers of the secondary winding on the middle transformer coil (since this one would probably have the greatest temperature rise). Leads from this device connect to an indicating and recording temperature meter. Also, an alarm rings if the winding temperature exceeds 90 degrees Centigrade. This alarm will sound before the conventional oil temperature alarm operates. Thus the furnace operator has a continuous record of the transformer temperatures under load and a warning when the danger point is approached.

Infrared Drying Assembly

The use of infrared drying lamps augments the standard gas-fired oven in the shop of the Davidson Electric Company, Brooklyn, New York. When originally considering infrared lamps



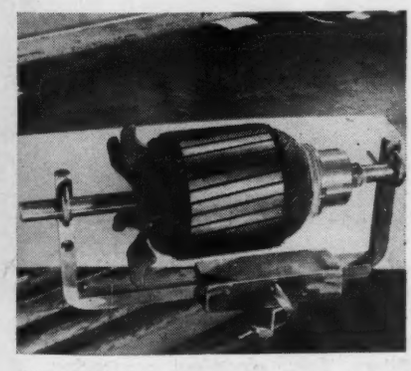
Series of outlet boxes, extension cords and individually-adjusted infrared lamps result in a versatile arrangement of heating units for rapid baking.

for drying purposes, one of the questions discussed was the advisability of installing a rigid assembly. Flexibility was considered an important point, however, and the present provisions, while not elaborate, provide for this necessary requirement. Each lamp is supported by a separate adjustable arm. Lamps can be swivelled in any desired direction and arms are provided with clamps so that they can be raised or lowered along vertical steel mounting shafts and fastened at any elevation. Vertical mounting shafts are supported by heavy, round base plates. This arrangement permits shop workers to quickly move standards to any location, fix the mounting at any height and azimuth, and swivel lamps for most effective use. Lamps are block-connected to flexible rubber-insulated extension cords which are, in turn, connected to a series of outlet boxes served by a common conduit and mounted 4 feet above the shop floor along one wall. Connections of adjacent extension cords are rotated between alternate legs of the 3-phase service so that the heating load can readily be balanced. When lamps are not in use, lamps are disconnected and extension cords are looped over pipe hangers located above the series of outlet boxes.

Adjustable Stand For Small Armatures

One of the latest shop equipment developments made in the small motor department of the Willey-Wray Electric Company, Cincinnati, Ohio, is an adjustable bench stand for holding small armatures. Basically, it consists of two L-shaped arms that slide in a steel collar that can be rotated 360 degrees.

Two 18-inch lengths of $\frac{5}{8}$-inch key stock, each bent to form a 5-inch upright, form the arms. The remaining 13-inch horizontal sections provide the adjustment for various armature shaft lengths. Three holes were drilled in



Adjustable small armature stand mounted to workbench.

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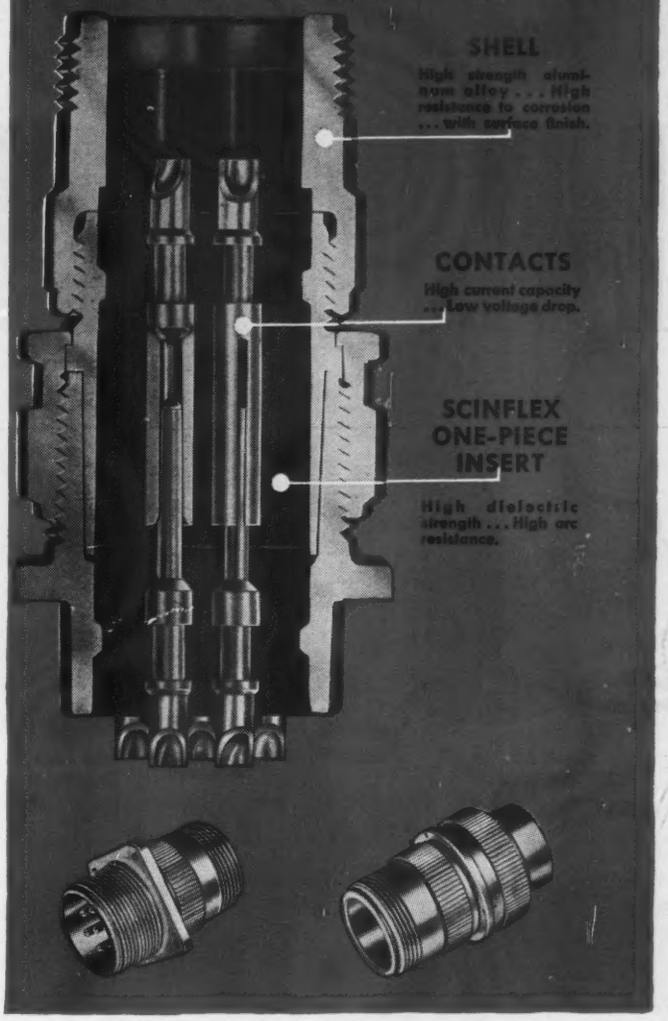
the finest ELECTRICAL CONNECTORS money can build or buy!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SCINFLEX ONE-PIECE INSERT
High dielectric strength . . . High arc resistance.

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Bendix-Scintilla* Electrical Connectors are precision-built to render peak efficiency day-in and day-out even under difficult operating conditions. The use of "Scinflex" dielectric material, a new Bendix-Scintilla development of outstanding stability, makes them vibration-proof, moisture-proof, pressure-tight, and increases flashover and creepage distances. In temperature extremes, from —67° F. to +300° F., performance is remarkable. Dielectric strength is never less than 300 volts per mil.

The contacts, made of the finest materials, carry maximum currents with the lowest voltage drop known to the industry. Bendix-Scintilla Connectors have fewer parts than any other connector on the market—an exclusive feature that means lower maintenance cost and better performance.

*REG. U.S. PAT. OFF.

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• Moisture-proof, Pressure-tight • Radio Quiet • Single-piece Inserts • Vibration-proof • Light Weight • High Arc Resistance • Easy Assembly and Disassembly • Less parts than any other Connector

Available in all Standard A.N. Contact Configurations

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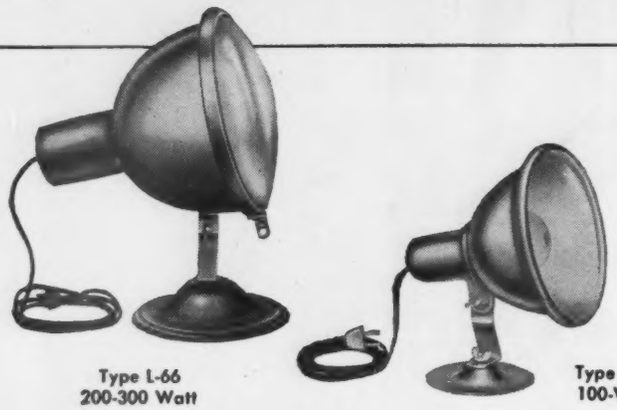

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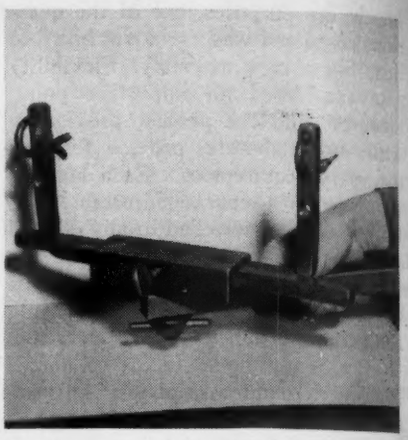


Unit removed from bench support to show assembly details.

each upright, the first close to the top, the others on 1¼-inch centers. A U-shaped bolt with a 2-inch thread and wing-nut fits into two of these openings and holds the armature shaft. The third hole is for opposite positioning.

Support for the arms is provided by a steel collar made from a 6-in. by 2-in. by 1¼-in. block. A slot was milled to seat the arms and covered with a ⅛-inch steel plate welded at the four corners. A 5/16-in. thumb screw in one side of this collar locks the arms securely in place after adjustment.

The arm assembly is mounted to one end of a 16-inch length of 1-in. square steel tubing by a 2¾-inch stud bolt and wing nut; can be rotated 360 degrees and locked into position at any point. The outer end of this tubing bracket telescopes into a 12-inch length of 1¼-inch square steel tube mounted to the underside of the workbench. Back and forth adjustment to suit operator is provided by a thumb screw.

Should the mechanic want to mount the armature at an angle, he merely loosens one of the U-bolt wing nuts and turns the bolt around.

All-aluminum electrical distribution is a new experience for chief engineer Irving D. Dischinger and project manager Joseph Benson of Fischbach & Moore, Inc., electrical contractors at the new Davenport, Iowa, rolling mill of the Aluminum Company of America.

Gas Burner Is Part Of Stripping Table

A multi-jet gas burner is mounted in the center of the stripping table in the motor repair shop of the L and P Electric Company, Brooklyn, New York. Gas pressure is regulated by means of a hand valve and the gas is fed to the burner through a pipe line which runs from the valve down to the base of the stripping table and then upwards to

Revolving stripping table has gas feed line in center. Various sizes of burners can be slipped over the feed so that, for rotors of various inside diameters, gas flames are kept close to the coils to be burned.

the burner through the center column of the table. Various sizes of burners are kept handy so, depending upon the inside diameter of the stator on the table, the gas flames impinge directly upon the windings to be burned. The burners consist of metal cylinders of the desired diameters. The top is sealed, the bottom is fitted with a collar which snugly fits around the gas feed line, and the walls of the cylinder are perforated so that 50 or more flames are directed outwards towards the windings.

In heating the windings, the rotor is placed on the table top and held firmly to this surface by means of hooked anchor bolts that grasp the upper lip of the rotor and are tightened by hand bolts beneath the table. The table revolves on roller bearings so that, after coils are heated, the table can be turned as cables are removed. For local heating, a standard torch is available.

By keeping the flame as close as possible to the windings being burned, maximum efficiency is achieved, the consumption of gas is reduced and heating periods are minimized.

Accommodates a Broad Range of Cable Sizes Gets the Job Done Faster . . . Easier!

Frankel Split Bolt Connectors are easy to use on all types of connections, whether temporary or permanent. A proven favorite for taps, dead ends, motor leads, and in junction boxes, etc. For working in close quarters or mean spots, you can't find a better connector than a Frankel "Bug."

• *compare these advantages!*

1. Extra length pressure bar extending beyond nut, keeps threads firmly meshed, prevents stripping.
2. Extra wide wrench grip on body.
3. No sharp edges to nick wires.
4. All material guaranteed against season cracking.
5. Nut of high strength Duronze.
6. Pressure Bar is a bronze forging.
7. Body is 90% copper (comml. bronze).

•

Write today for Catalog 4B
SOLD THROUGH LEADING WHOLESALERS EXCLUSIVELY

KEEP FRANKEL "BUGS" HANDY — YOU'LL USE THEM EVERY DAY

Frankel Solderless Connectors

FRANKEL CONNECTOR CO.
27 VESTRY ST. • NEW YORK 13, N. Y.

42 YEARS OF KNOW-HOW IN SOLDERLESS CONNECTORS

General Electric Announces
2 ALL-NEW Time-Delay Fuses
THAT MAKE YOUR PROTECTION EXTRA SURE!

all-new

FERRULE FUSE

This easy-to-renew fuse has a combination of *protection* features and *convenience* features such as you've never had before. Thanks to a newly designed fuse link perfected by General Electric research, protection from harmful overloads is quick and sure — yet, limited transient overloads won't cause unnecessary "blows."

It's a timesaver, too. Only three parts enclose the link. Alignment takes care of itself when a new link is slipped in place. It can't be assembled with the link off-center or under strain. Caps come off and go on by hand. A new label makes identification easy.

You'll be buying these fuses in ratings from 3 to 60 amperes, for 250- or 600-volt requirements. Order a trial lot from your electrical supply house now, and watch them pay off as "headache preventers."

all-new

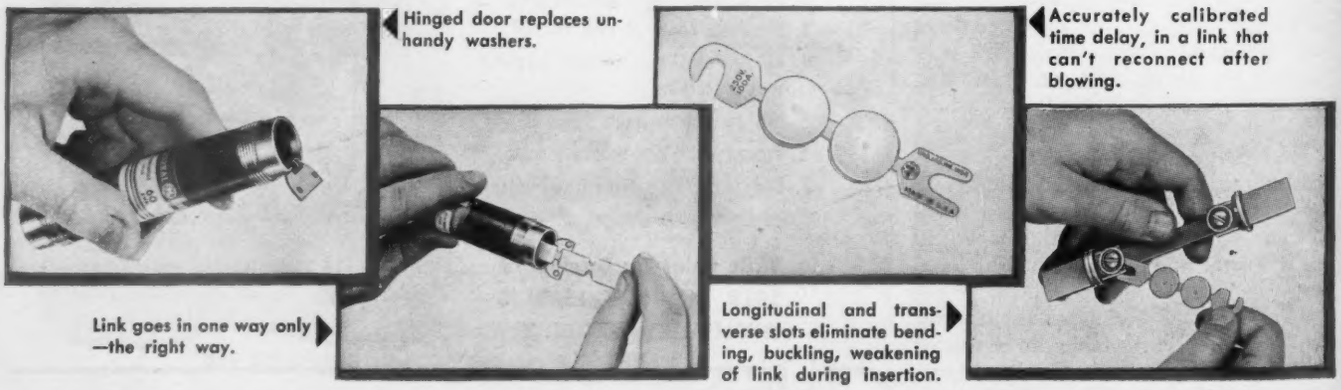
KNIFE-BLADE FUSE

You won't know which to rate "tops" in this design: the new time-delay link, or the sturdy assembly that makes such short work of renewal. Just remove one end-cap, and the fuse is disassembled. Screws can't fall out, and cup-shaped washers guide the link into place. The heavy-fiber bar-support is securely anchored to the blades. Alignment is bound to be right, even on large size fuses with more than one link.

Notice the disk design of the link sections. No chance here for "blown" link sections to overlap and re-establish contact.

This new fuse line includes ratings from 70 to 600 amperes, for 250- or 600-volt service. Try them once and you'll want them as your *first-choice* fuses.

For facts on new G-E fuses write to Section D13-718, Construction Materials Department, General Electric Company, Bridgeport 2, Connecticut.


Hinged door replaces unhandy washers.
Accurately calibrated time delay, in a link that can't reconnect after blowing.
Link goes in one way only —the right way.
Longitudinal and transverse slots eliminate bending, buckling, weakening of link during insertion.

GENERAL ELECTRIC

Equipment News

Time Switch

A new time switch, Type T-47, rated 35 amperes at 115 and 230 volts and timed and operated by the synchronous, self-starting, permanently lubricated Telechron motor, has been announced. It has wide application on farms, in stores, small industries and in homes and apartments. Designed for on and off timing of a single circuit, the new switch will perform one on and one off operation during any 24 hour period and will continue to do so daily without adjustment. The switch has a single pole, single throw mechanism with large, silver, snap action contacts. It is equipped with a 24 hour clock dial. Operation can be manual or automatic. Adjustable, switch tripping clamps attached to the dial are used for setting the switch. They are designed to save electricity by turning off lights and appliances when not needed, save time by releasing motor and machine operators for other work, and to prevent waste and spoilage by automatic control of heating, lighting, fans, and blowers. General Electric Co., Schenectady, N. Y.

Troffer Downlight

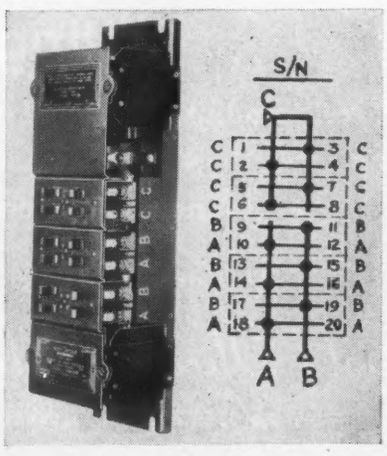
The recessed troffer downlight for use in stores, offices and other places where a concentrated light is desirable, has been announced. Designed for individual, end, corner, cross-over and in-line mounting with standard width fluorescent troffers, it may be installed in acoustical and other types of ceilings. It utilizes a silvered-glass Permaflector and a standard 200 watt incandescent lamp, and is adjustable in a complete circle up to a 35° angle. It has concentric louvers. The housing, 12 in. square by 10 in. deep, is equipped with knock-outs for attachment to troffers. Pittsburgh Reflector Company, Oliver Building, Pittsburgh 22, Pa.

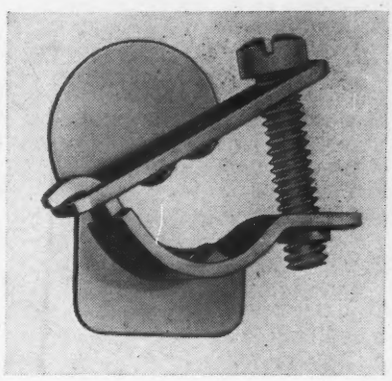
Multi-outlet Assemblies

A new multi-outlet assembly, called Snapicoil, has been developed. Consisting of standard No. 1927 plug receptacles wired with two No. 12 Type R conductors, this wiring harness will be furnished four ways: 19C12, 25 foot coil with 25 outlets 12 in. on centers; 19C24, 50-foot coil with 25 outlets 24 in. on centers; 19C36, 100-foot coil with 33 outlets 36 in. on centers; and, for those places where a cluster of outlets closely spaced is desirable, 19C03, 18 in. coil with 6 outlets 3 in. on centers. Each coil will be furnished with No. 1900C cover section cut to length for installation between receptacles. The Wiremold Company, Hartford 10, Conn.

Panelboard

A system of branch circuit terminal markings is incorporated in this new circuit breaker "plug-in" panelboard. The three phase 4 wire arrangement of the NMO panelboard eliminates doubt as to phase identification of branch circuits by including letters A, B and C opposite each branch circuit load terminal connected to the corresponding three phases. A marking strip with black background for phase A, red for phase B and blue for phase C is used. A split-bus arrangement provides for distributed phasing of A and B circuits and group phasing of C circuits. Two pole 208 volt circuits can be obtained in addition to the usual single or two pole 120 volt circuits, by connecting to adjacent A and B terminals. Breaker units are the high speed thermal-magnetic, coilless, trip type, providing two way circuit protection. Similar designs are available for both single phase, 3 wire and three phase 4 wire services with 15, 20, 30, 40 and 50 ampere branch circuits. Square D Company, 6060 Rivard Street, Detroit, Mich.





Connector

A new No. 9049 "EZ" connector for connecting non-metallic sheathed cable to device and outlet boxes has been announced. It is formed of pressed steel, electro-galvanized, and is of the "rock-in" type. One of the features is the design and action of the hook that protrudes from the lower plate, up through a slot in the upper strap. When loomwire is inserted in the connector, the upper strap moves up and engages on the upper portion of the hook. This movement forces the integral flange, which is "rocked-in" through the knockout of the box, to position itself off center. Neither the top nor bottom integral flanges can be pulled through the knock-out without first removing the cable from the "EZ" connector. Underwriters Laboratories has approved the connector for installation with loomwire or non-metallic sheathed cable of sizes No. 14/2, 14/3, and 12/2 and 12/3. National Electric Products Corp., Chamber of Commerce Building, Pittsburg, Pa.

Portable Threading Machine

This electrically powered pipe and bolt threader is known as "Tom Thumb" No. 582. Standard range is ¼ in. to 2 in. pipe. Extra range ⅛ in. pipe. Range with special drive shaft 2½ in. to 8 in. pipe. Bolt range ¼ in. to 1½ in. pipe. Nipples as short as 3½ in. in the 2 in. size can be threaded on both ends without using a nipple chuck. Pipe or studs as short as 2½ in. can be threaded on one end. A new front chuck known as the "Spinfast" eliminates need of a chuck wrench. Motor is universal, reversible, variable speed for 110 volts, either a-c singlephase or d-c. Drive from motor by V belts eliminates noisy gears, prevents mechanical shock and overload. V belts protected from oil and grease. The Oster Manufacturing Co., 2085 East 61st Street, Cleveland 3, Ohio.

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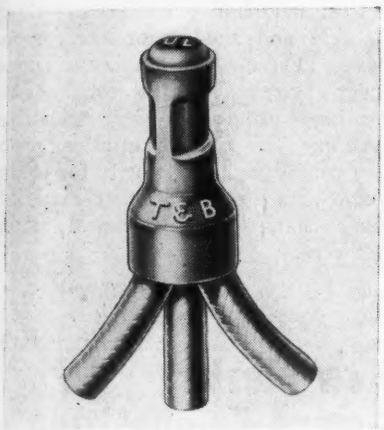
midwest electric mfg. company
1639 walnut street chicago 12, ill.

Transformers

A new line of silicon-glass insulated, dry-type network transformers for buildings, sidewalk and street vaults has been announced. Transformers are sealed hermetically by welding and can operate when submerged by flooding. They are filled with dry nitrogen permanently sealed in place. Cases are constructed of copper bearing steel to resist corrosion. Bottom of transformer has special under coating. Units are available in both 5 kv. and 15 kv. classes in sizes of 150, 225, 300, 500, 600, 750, and 1000 kva., three phase. High voltage switches and low voltage network protectors can be supplied either mounted on transformer or for separate mounting. Westinghouse Electric Corp., Pittsburgh, Pa.



Insulated Wire Joint

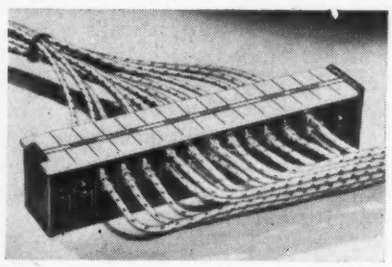
A new and specialized solderless wire joint designed to meet the requirements of fixture and appliance manufacturers has been announced. Construction consists of high-strength, high dielectric insulation permanently molded around a seamless bronze barrel that becomes an integral part of the connector. Its design permits both complete connection and insulation of wiring in one operation. Other features include approval by Underwriters' Laboratories for a wide range of wire sizes and combinations, an insulation bell that accommodates a wide range of insulation diameters. Available in any standard color for wire. Thomas & Betts Co., Elizabeth, N. J.

Fluorescent Fixture

A new commercial slimline fluorescent lighting unit has been announced. Two four-foot sections, packed in a single carton and designed to couple together form a single streamlined 8-foot fixture. Sections slide into individual mounting tracks and are fastened together by bolts. A louver unit hooks onto the basic four light fixture. Slimline may be mounted flush or pendant, individually or in continuous rows. The basic open type four light unit is available with 200 milliamp ballast or 300 milliamp ballast. It carries Underwriters' approval and is for operation on 110-125 volt 60 cycle a-c. Mitchell Manufacturing Company, 2525 Clybourn Avenue, Chicago 14, Ill.

Remote Control Wiring System

This new remote control wiring system has five components—one type of switch, switch box, relay and transformer; and two types of wire. The relay is of split coil design: one coil to close the 115 volt circuit, the other coil to open it. Operating on 25 volts, the relay is equipped with two binding screws for the 115 volt connections and three binding screws for the 25 volt connections. It is small enough to be mounted from the inside of a standard outlet or switch box through any convenient half inch knock out. This leaves the high voltage end inside the box while the low voltage end protrudes to the outside. The box forms the partition between the high and low voltage. The two high voltage binding screws are connected like a regular single pole switch. Switch is a single pole, double throw momentary contact switch which is normally open. As many switches as desired may be connected in parallel, however, not more than three relays should be controlled from one switch with the recommended transformer, G-E 72G41. Switch box is available for flush mounting of from one to three switches. The wire is No. 22 solid-conductor Flamenol-insulated cord of small dimensions. Either two or three wire cord is available. General Electric Co., Bridgeport, Conn.



Terminal Block

This terminal block, known as Crablok, permits rapid disconnection as well as positive locking of terminal leads. Terminal strip is in several lengths, and in either single or double-tier types. Individual strips are placed end-to-end to provide any number of connections necessary. Spring-loaded socket connectors are mounted into channels in Crablok, either single or double-tier. Socket connectors are available in two sizes to accommodate contact tips for range of conductors from No. 20 through No. 8 AWG. In making quick-disconnect connections, contact tip is inserted into spring-loaded socket connector which grips tip firmly and provides electrical connection. It is normally used in 220 volt service but can be used for higher voltage service up to 600 volts by insulating contact tips with plastic sleeves. Burndy Engineering Company, Bruckner Blvd., New York 54, N. Y.

Electric Timer

A portable all-electric timer, known as "Portable AF", for automatically shutting off window and other portable fans after any pre-selected time has been announced. Housed in an anodyzed aluminum case, unit is available in two time ranges, 0 to 10 and 0 to 20 hours. Timer cord is plugged into any convenient outlet; fan cord, in turn, is plugged into the receptacle at the bottom of the case. Key hole slots are provided at the back for convenient mounting. Rated at 10 amps., ⅓ hp., 115 volts a-c., it can be used with any make of window fan. Paragon Electric Company, 1271 Adams Street, Two Rivers, Wis.

Electric Plants

Two new lines of Diesel electric plants, air cooled and water cooled, completely equipped and self contained have been developed. Air cooled plants are available in a-c models of 2500 watt capacities, 60 cycle, and voltages of 115 or 230, single phase, or 115/230 volt, single phase, three wire, or 230 volt, three phase, three wire. Standard accessories include two 6 volt starting batteries connected in series, oil filter, oil bath air cleaner, muffler, two flexible fuel lines, hand crank and one extra fuel injection pump, holder and nozzle. Water cooled plants, in 10,000 to 35,000 watt capacities, are operated by Buda diesel engines. Available for a-c, 60 cycle, single and three phase, all standard voltages; they are enclosed in weather proof, sheet steel housings with removable side panels for servicing. A welded steel battery and accessory rack contains two six volt starting batteries. D-C models of 10 and 15 kw. available in either 115 or 230 volt. D. W. Onan and Sons, Inc., 43 Royalston No., Minneapolis, Minn.

(*Continued on page 220*)

In the News

Alvah Small Elected Vice Chairman

Alvah Small, President of Underwriters' Laboratories, Inc. since 1935, was elected Vice Chairman at a special meeting of the Board of Trustees, held in New York.

Born in South Portland, Maine, Mr. Small's first experience was serving as an Inspector for the New York Fire Insurance Exchange. He joined the Laboratories' staff in 1906, and in 1910 was placed in charge of the factory inspection work. In 1916 he became Vice President, and in 1935 was elected President. For 23 years he has been Chairman of the Electrical Committee of the National Fire Protection Association, and in this capacity had charge of the compilation, amendment, revision and publishing of the "National Electrical Code," the most widely adopted and observed safety code in the United States.

Upon Mr. Small's assumption of the duties as Vice Chairman, Curtis R. Welborn, since 1947 Executive Vice President, was elected President of Underwriters' Laboratories, Inc. Mr. Welborn joined the Laboratories' staff in Chicago in 1920 as Assistant Engineer of the Gases and Oils Department. In 1924 he was appointed Superintendent of Label Service; in 1935 was elected Secretary, which position he held until his appointment as Executive Vice President in 1947.

IES Elects L. E. Tayler President

The Illuminating Engineering Society has elected Lee E. Tayler of the Detroit Edison Co., Detroit, Michigan, as President of the Society for a term of one year, according to a recent announcement. Mr. Tayler will take office October 1, 1948.

Other officers elected to serve with Mr. Tayler are: General Secretary—A. H. Manwaring, Philadelphia Electrical & Mfg. Co., Philadelphia, Pa.; Treasurer—E. M. Strong, Cornell University, Ithaca, N. Y.; Vice-President—Walter Sturrock, General Electric Co., Cleveland, Ohio; Directors—Myrtle Fahsbender, Westinghouse Electric Corp., Bloomfield, N. J.; Hoyt Steele, Benjamin Electric Mfg. Co., Des Plaines, Illinois.

Mr. Tayler has been identified in the field of illumination for more than 20 years. As a member of the I.E.S., Mr. Tayler has served on numerous committees as member or chairman. He has served as Chairman of the Michigan Section and as a Director of the Society for a 3-year term. Prior to his election as President, he has served as General Secretary of the Society and as Vice-President for the past two years.

Allocation of Materials

Allocation of scarce industrial materials, including steel and other metals, again is being talked in Washington. But it's still just talk.

Important Congressional sentiment is forming in behalf of some form of controls. The President's advisors are drawing up several plans for revision of the present voluntary allocation program.

Idea behind all this thinking is that the government soon must take steps to prevent a mad scramble for raw materials. The voluntary program was set up to insure the government's commitments for foreign aid and national defense and to take care of key industrial expansion. These needs alone, it has been estimated, will take more than half the nation's steel production, for example. And the voluntary allocation program is not even doing that job.

Best bet among the plans being formulated by Administrative agencies is a scheme to amend the voluntary allocation law to permit almost unlimited industrial agreements. This would eliminate existing anti-cartel provisions of the existing law. Thus, the Justice Department would not be allowed to veto allocation agreements it deemed "monopolistic." Nor would public hearings be held on all allocation plans, as now required.

Truman aides hold that anything further than conservative modification of the existing voluntary allocations would be politically impossible at present. Nonetheless, the White House may again ask for real government rations, along WPB lines, with the full knowledge that Congress would not go along.

Behind the present planning for controls is the sweeping plan drawn up by the National Security Resources Board, which would set up full controls for future use in event of war, plus some immediate allocations of scarce materials. Accent of this proposal was on obtaining requirements of the military. It has been rejected by the White House.

Most talked of scarcities are those in steel and the major non-ferrous metals. These would get first attention under any revision of the voluntary allocations program. Key industries, including the electric utilities, probably would get high priority for equipment, with steel and other materials being channeled to electrical manufacturers.

New Merit Award Competition

The new Official Rules for the $1500 Planned Lighting Merit Award Competition sponsored by the Third International Lighting Exposition, have been released. In addition to continuing many of the regulations of last year's competition, several new rules have been added that should prove of special interest. Requests for Official Rule Booklets and application blanks should be addressed to Merit Award Committee, Room 818, 326 West Madison Street, Chicago 6, Illinois.

Requirements for entering have been further simplified and standardized; the scope of the contest has been widened by adding a fifth group to be eligible and the total number and amount of Gold Seal Awards has been increased; the nature of the material expected from entrants is more specifically defined and provisions are made for even greater recognition and publicity for winning awards.

"Already we are receiving many requests for Official Rules Booklets and Entry Blanks from those who wish to enter this year's $1500 Gold Seal Merit Award Competition," says R. D. Bradley, Chairman of the Merit

Award Committee. "In supplying these requests we are able to benefit by our successful experience in last year's Competition which attracted many hundreds of entries and resulted in 157 Merit Award Winners."

"In formulating the new rules we have retained the best features of last year's Competition and added others which had been suggested. We expect this new competition with even simpler rules and wider range of field to draw many more entrants and to attract even wider attention and favorable comment".

Some of the outstanding highlights of the new Official Rules are: There are five separate competitions, one for each of the following groups:

1. Electrical Contractors
2. Utility Lighting and Power Representatives
3. Architects and Consulting Engineers
4. Electrical Wholesalers; Owners, Lighting Specialists and Salesmen
5. Industrial and Commercial Owners and Users of Lighting.

Three Gold Seal Awards of $100 each, will be given in each of the classifications or a grand total of $1500.

Judging will be intra-group—that is, a submittal by an electrical contractor will compete with only those of other electrical contractors, etc., and awards will be decided accordingly. In addition, where the installation is the cooperative work of two or more men of the above classifications, the entry may be submitted by the two or more involved as a joint entry and entered in one or more of the applicable classifications.

All entries are to be limited to the Planned Lighting solution of a single specific lighting problem, such as one in which the area could be shown in a single photograph. However, this does not limit the number of photographs of drawings which may be used.

Number one consideration in judging the reports will be their merit in terms of the customer benefits shown. Consideration will also be given to the arrangement of the reports or statements lending themselves to ready and forceful use with customers and prospects; to the photographs or layouts submitted; and to amplifying or supporting details including such evidence as the customer's statement.

While the competition does not close until midnight January 15, 1949, entrants are urged to send in at once, the entry blank which appears on the back of the Rules Booklet. They will then be sent a registration number to affix to their entry. The names of the participants will thus be unknown to the five impartial judges, assuring absolute

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"BUFFALO" TYPE "E" BLOWERS AND EXHAUSTERS

Give long term satisfaction

It's the kind of satisfaction that builds up *your* reputation, too! We have been building these rugged, compact, fans for a good many years. In these years, we've seen "Buffalo" Electric Blowers give as high as 36 YEARS of up-to-capacity service on the job! Four sizes, 30 to 450 cfm at varying pressures up to 3.65". Constant and variable speed models, to operate on any 110 v. or 220 v. direct current or 25, 40, 50 or 60 cycle single-phase alternating current. *Write for Bulletin 3222-F, and prices.*

IDEAL FOR
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— forge blowing
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— exhausting in many cleaning operations

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CUTTING COSTS IN EVERY BRANCH OF INDUSTRY

Step down main circuit voltages

—with CHICAGO
Power Circuit
TRANSFORMERS

• Convenience In Wiring — Attached outlet boxes provide large, easily accessible wiring compartments for lead connections, take conduit or flexible cable from all 4 sides.

• Flexibility In Mounting — Units can be mounted as shown at right, up-side-down, or in any other position; rugged frames and mounting feet provide strong, rigid support.

• Dependability In Operation — Quality construction, with more-than-adequate insulation and vacuum impregnation of core and coil, assures long, service-free operating life.

Write for prices and further details.

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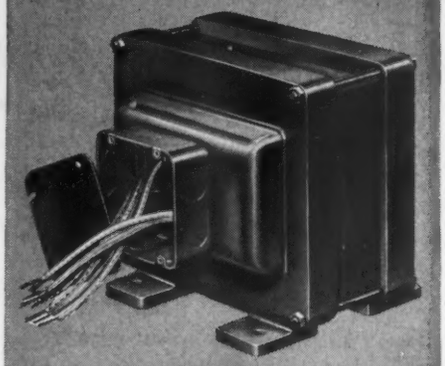

Primaries
230/460 or 575 Volts
(50/60 Cycle)

Secondaries
115 or 115/230 Volts
½ to 10 KVA

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Division of Essex Wire Corporation
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THE MAGNO-TRONIC FLUORESCENT STARTER

PROTECTS	Fully, automatic thermal relay with unusually long life that eliminates blinking lights and protects all auxiliary equipment.
SIMPLIFIES	Replacement of worn-out lamp automatically restores closed circuit—replacement of starter unnecessary. No button to push.
REDUCES COSTS	Magno-Tronic starters provide exact timing in the lamp electrode—preheating process preventing excessive loss of emission material, thereby assuring the maximum in the useful life of a lamp. The established quality of this starter saves considerable time in maintenance and man hours required to repair and/or replace an inoperative lighting unit.
VERSATILE	Will operate efficiently over an extended voltage range under widely varying temperatures.

GUARANTEED FOR ONE YEAR.

The (SP-15-20) for use with either 15 or 20 watt lamps
The (SP-30-40) for use with either 30 or 40 watt lamps
The (SP-100) for use with 100 watt lamps

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INDUSTRIAL ELECTRONICS CORP.
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fairness in the selection of the winners.

The judges are Carl Zersen, Chairman, Mgr., Chicago Lighting Institute; Marshall Waterman, Electrical Testing Laboratories, Inc.; B. J. Martin, Publisher and Editor, *Electrified Industry;* W. T. Stuart, Editor, *Electrical Construction and Maintenance;* John O. Kraehenbuehl, Professor, University of Illinois.

Awards will be conferred at the opening conference session on March 29, 1949, starting at 9:30 A.M. Successful entries will be placed on display at the Third International Lighting Exposition and Conference, Stevens Hotel, Chicago, March 29 to April 1, 1949.

Book Reviews

Gaseous Discharge Lamps

The essential data required for a complete working knowledge of fluorescent and other gaseous discharge type lamps has recently been published in a 304-page book. Included in the coverage are fluorescent lamps, photoflash lamps and tubes, infra-red telescopes and signal devices, sun and germicidal lamps, and fluorescence in television.

The many factors influencing the design, construction, operation and performance of gaseous discharge lamps are covered analytically. Beginning with a discussion of light, radiation and the discharge of electricity through gases and vapors, it extends to fluorescent light principles, components, problems, efficiency, and related factors. Much discussion relates to phosphors, including natural and synthetic types, activators and their effect, factors affecting the brightness of phosphors, and other basic considerations.

Operating characteristics of fluorescent lamps are discussed in detail, including functions of ballasts, starting switches, various types of circuits, and the effect of power factor, temperature and similar factors. Quality of lamps, color quality, color control, and factors determining efficiency are also covered.

Much experimental and design data are included which have been drawn from both published and unpublished work of engineers in the various lamp and related laboratories in which the development of phosphors, oxide-coated cathodes, and fluorescent lamps has been done.

All present-day electrically operated light sources are based upon the discharge of electricity through a gas or vapor, with the exception of carbon- and tungsten-filament incandescent lamps and the photoflash lamp. This

coverage of the basis of operation of the fluorescent lamp and some of the other popular types of discharge lamps is thus very timely.

The authors of "Fluorescent and Other Gaseous Discharge Lamps" are William E. Forsythe, Physicist, and Elliot Q. Adams, Physical Chemist, both of the Incandescent Lamp Department, General Electric Company. The book is 6 x 9 inches, contains 152 illustrations, and is published by Murray-Hill Books, Inc., 232 Madison Avenue, New York, 16, N. Y. Price is $5.00.

Dates Ahead

Second International Store Modernization Show—Grand Central Palace, New York, N. Y., July 6-10.

International Association of Electrical Inspectors — Western Section, Denver, Colo., September 13-15; Northwestern Section, Salt Lake City, Utah, September 20-22; Southwestern Section, Oakland, Calif., September 27-29; Eastern Section, October 11-13; Southern Section, Heidelberg Hotel, Jackson, Miss., October 18-20.

Illuminating Engineering Society — National Technical Conference, Boston, Mass., September 20-24.

Electrical Contractors Society of Washington States — Annual convention, Everett, Wash., September 25-26.

International Municipal Signal Association—53rd Annual meeting, Hotel Statler, Buffalo, N. Y., October 4-7.

Porcelain Enamel Institute — Annual forum, University of Illinois, Urbana, Ill., October 13-15.

National Association of Housing Officials—Third annual exhibit of building and maintenance products, Olympic Hotel, Seattle, Wash., October 13-16.

National Electronics Conference—Edgewater Beach Hotel, Chicago, Ill., November 4-6.

National Electrical Manufacturers Association—Traymore Hotel, Atlantic City, N. J., November 8-13.

Electrical & Gas Association of New York, Inc.—Luncheon meeting, Grand Ballroom, Hotel Astor, New York, N. Y., November 17.

National Electrical Contractors Association — 47th Annual Meeting, Roney Plaza Hotel, Miami, Fla., November 30-December 3.

Electrical & Gas Association of New York, Inc.—Luncheon meeting, Grand Ballroom, Hotel Astor, New York, N. Y., December 22.

Independent Electrical Contractors Association, Inc.—43rd Annual dinner, Hotel Astor, New York, N. Y., January 15, 1949.

American Institute of Electrical Engineers—Winter general meeting, Pennsylvania Hotel, New York, N. Y., January 31-February 4, 1949.

National Electrical Manufacturers Association—Winter convertion. Edgewater Beach Hotel, Chicago, Ill., March 13-18, 1949.

Third International Lighting Exposition and Conference—Hotel Stevens, Chicago, Ill., Week of March 28, 1949.

Manufacturers News

A. A. WATSON NAMED SALES MANAGER OF TRUMBULL

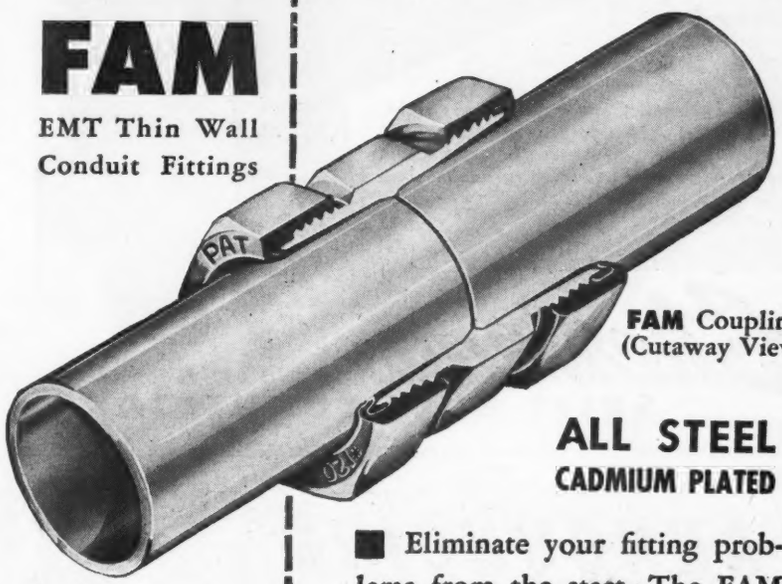
Allan A. Watson has been appointed sales manager of the Trumbull Electric Manufacturing Company, Plainville, Conn. In this new capacity Mr. Watson will be responsible for all field sales operations of the company.

He joined the Trumbull sales organ-

Underwriters' Laboratories Approved as Raintight UL

FAM

EMT Thin Wall Conduit Fittings

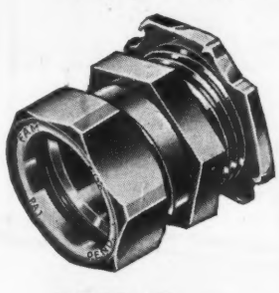


FAM Coupling (Cutaway View)

ALL STEEL
CADMIUM PLATED

■ Eliminate your fitting problems from the start. The FAM coupling has only three parts—and no rings to cock or lose. It's precision machined to bite deeply into the conduit surface for sure, positive ground, and a raintight seal. And better yet, FAM couplings can be used over and over again.

FAM Connector



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for Descriptive Literature

FAM *Features*

1. Simple, fast installation
2. No rings to cock or lose
3. Precision machined taper fit
4. Cuts surface for positive ground
5. Raintight—UL Approved

Buy FAM couplings and connectors—they will merit your continued confidence

FISHER-ARMOUR MFG. CO.
757 Waveland Avenue
Chicago 13, Illinois

Perfect Mates!

With or Without Nut Retainers

This Sherman Connector assures tight, permanent, ***dependable*** wire connections, without excessive wrench torque, because threads on both body and nut are machine cut, and checked with precision gauges to mate perfectly.

H. B. SHERMAN MFG. CO.
Battle Creek, Mich.

Sherman
SPLIT BOLT CONNECTORS

ANNOUNCING
—a 25% price reduction!
PLUS—a NEW line of drills!

NOW 25% LESS

ROUND DRILLS

Yes, these economical CARBOLOY Masonry Drills for shallow drilling now cost 25% less!

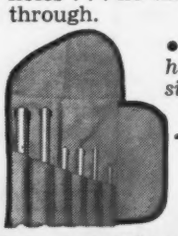
- It's an *all-purpose* line of drills in a *wide range* of sizes—at *lowest* prices.
- CARBOLOY Drills cut through masonry up to *four times faster.*
- They stay sharp up to *50 times longer,* because they're tipped with Carboloy Cemented Carbide — *the hardest metal made by man.*
- They fit drill presses, portable electrical drills or hand braces.

NEW UNIVERSAL DRILLS

FLUTED DRILLS

Here's a NEW line of CARBOLOY Masonry Drills for drilling all holes, shallow or deep!

- They do *rotary* drilling — *quieter* drilling, and make cleaner, true-sized holes . . . no chipped edges or breakthrough.



- *Also available in handy canvas kits of six.*

Three Assortments $10.40, $12.45 and $15.25

CARBOLOY COMPANY, INC.
11175 E. 8 Mile Road, Detroit 32, Michigan

WRITE FOR FREE FOLDER SA 236

CARBOLOY® MASONRY DRILLS

A. A. WATSON

ization in 1936 and three years later was appointed assistant to the sales manager. In 1946 he was named manager of the company's plant at Norwood, Ohio and served in that capacity until his present appointment as sales manager.

Henry A. Samer has been appointed works manager of the Norwood, Ohio plant.

G-E CHANGES

Earl O. Shreve, vice president of the General Electric Company on the president's staff and president of the U. S. Chamber of Commerce, has retired from the company after 44 years of service. Mr. Shreve has been on special assignments with headquarters in New York. He previously was in charge of customer relations.

The Construction Materials Department, a new operating department of G-E, has been established. C. D. Hepler, formerly vice president in charge of marketing for the Trumbull Electric Manufacturing Company, a G-E affiliate, has been named general manager of the new department. Headquarters are at Bridgeport, Conn.

The new department will be responsible for the products of the following present divisions of the appliance and merchandise department: wire and cable, wiring devices, accessory equipment, conduit products, Tungar and metallic rectifiers.

The appliance and merchandise department has announced changes in the titles and responsibilities of ten men.

Carl M. Lynge, formerly manager of manufacturing, has been appointed manager of employee and community relations for both the appliance & merchandise department and the newly formed construction materials department.

J. W. McNairy has been named manager of engineering and manufacturing for the appliance & Merchandise department.

A. M. Sweeney, formerly manager of appliance sales, has been assigned the post of general sales manager, while Charles W. Theleen, assistant manager of appliance sales, has become manager of sales.

George B. Park, who was previously public relations manager, has succeeded Arthur L. Scaife as advertising manager. Mr. Scaife becomes manager of merchandising.

Albert J. Brock, formerly assistant manager of construction materials sales, has been appointed manager of sales services of the appliance & merchandise department. In this position he will be responsible for the operations of the G-E Consumers Institute and Home Bureau and of the retail development and sales service sections.

Announcement has been made of the appointment of H. Arthur Howe as manufacturing manager of G-E's Compound Division, which produces phenol, phenolic plastic materials and magnesium oxide.

SILVRAY APPOINTMENTS

John L. Kilpatrick has been appointed vice president of Silvray Lighting, Inc., New York, N. Y. Mr. Kilpatrick joined the Silvray staff over a year ago as manager of lighting development. He has had nearly 25 years

J. L. KILPATRICK

experience in the field of illumination, approximately half of this time being spent with the Westinghouse Electric Corporation in both lamp and lighting division.

Frank A. Eustace has been appointed to head advertising and sales promotional activities.

SQUARE D SALES OFFICES REORGANIZED

The Square D Company has announced the appointment of three new regional managers.

S. T. Walz with headquarters at Atlanta will manage the Southeastern region, which includes the Atlanta, Charlotte, Jacksonville and Birmingham district offices. Mr. Walz was formerly Birmingham district office manager.

K. R. Morris with headquarters at Baltimore will be responsible for the Eastern region, including the Baltimore, Philadelphia, York and Rich-

Contractors: get this extra profit!

General Electric's New Wall Heater Will Tack Extra Profits On All Your Jobs — Low-cost — Easy To Install!

On your next job, talk the builder into installing G.E.'s Built-in Wall Heaters.

They're not only an extra-profit item for you, but they'll do an amazing selling job for the builder. For this heater is one of the new, modern features that people look for when buying houses.

The G-E Wall Heater warms up a room fast. Can be turned on from the bedside by an easily installed, remote-control switch. It works on the radiant convection principle.

General Electric Wall Heaters are inexpensive to install. Easy to build into any wall.

There's no chance of this heater setting the wall on fire. It's been approved by the Underwriters' Laboratories, Inc.

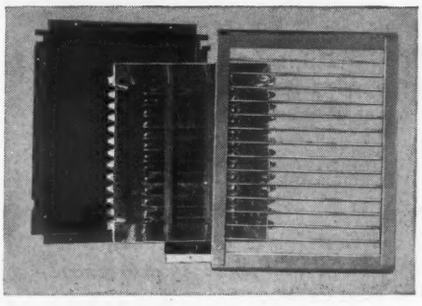
Mail coupon below for complete details.

Specifications for General Electric Built-in Wall Heater . . .

1. Comes completely equipped with tumbler switch as integral part.
2. Beautiful Hammertone gray finish—can be easily painted another color.
3. Fits flush with wall—guard projects only ⅝ of an inch.
4. Highly polished corrugated-aluminum reflector radiates heat in wide zone.
5. Protective grille of high-quality-steel wire—easily removed for cleaning.
6. Two long-life heating elements of nichrome wire—ceramic cores.
7. Rating—1320 watts, 115 volts, a-c/d-c, 4507 Btu-hr.
8. Size: 17⅛ inches high by 13⅛ inches wide by 4¾ inches deep. Wall opening, 14¾ by 11½ inches.
9. Shipping weight, 10 pounds.

Wonderfully low-priced

BUILT-IN ELECTRIC **WALL HEATER**



Heater is delivered in three parts. The wall box packed separately, so that the heater can remain safely packaged while wall box is being installed.

General Electric Co., Section 283-2J
1285 Boston Avenue
Bridgeport 2, Connecticut

Please send me complete information on General Electric's Built-in Wall Heaters.

NAME .....

ADDRESS .....

CITY .....

STATE .....

GENERAL ELECTRIC

ELECTRICIAN'S REAL FRIEND

L.G.W. ANGLE LOCKNUT PLIERS

First class electricians do not violate the code.

They are mechanics of the highest type.

They know the code was compiled by Electrical Engineers for the protection of life and property.

Their jobs must be jam up and so must the locknuts and bushings on their jobs.

L.G.W. Angle Locknut Pliers is the only tool that will tighten locknuts and bushings in outlet boxes in any position, the assurance of a perfect ground system.

L.G.W. Angle Locknut Pliers will cut and skin the ends of rubber covered wire.

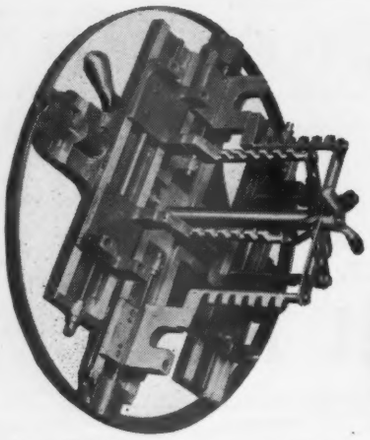
L.G.W. Angle Locknut Pliers will remove the burrs from the inside or outside ends of conduit or steel tube.

The screwdriver and hammer method of tightening locknuts and bushings is now history.

Your supplier will fill your order

White Manufacturing Co.

3802 Poe St. Dallas 4, Texas



COIL WINDING TAKES A HEAD!

For efficient, accurate coil production, the GC HEAD pictured above is without parallel in the electrical industry. Its construction embodies a cam collapse mechanism for all winding fingers which allows quick removal of coil groups and instantaneous repositioning for further winding.

Winding fingers are set to coil dimensions by screw adjustment and a complete setup can be made *in less than two minutes.*

Attachments are available for loop winding and single phase winding. Swivel End Finger attachment forms knuckles in the nose of the coils which removes strains, makes winding easier and reduces possibility of short circuits.

Can you be satisfied with less than the best?

• Write for descriptive literature on the GC HEAD and other winding equipment of our manufacture.

POTTER & RAYFIELD, INC.

ENGINEERING CRAFTSMANSHIP

P. O. BOX 1042C ATLANTA, GA.

mond district offices. Mr. Morris was formerly Baltimore district office manager.

R. W. Thompson with headquarters at St. Louis will manage the Midwestern region which includes the St. Louis, Kansas City, Moline and Omaha district office. Mr. Thompson was formerly Chicago office manager.

WESCO APPOINTMENTS

Westinghouse Electric Supply Company has opened a branch house at 610 North Washington St., Albany, Ga. H. L. Edge, Jr. has been appointed manager. Mr. Edge will report to W. A. Emerson, Southeastern district manager, with headquarters at Atlanta, Ga.

E. J. Brophy has been appointed Central New York state district farm sales supervisor with headquarters at Rochester, N. Y. G. W. Reber was named South Atlantic district farm sales supervisor, Baltimore; and J. D. Sherck was appointed Central district farm sales supervisor with headquarters at Detroit.

R. T. Shreve has been named district specialties sales manager at Chicago.

AMERICAN STEEL & WIRE APPOINTMENTS

Appointment of Earl N. Graf and Walter C. Anderson to newly created sales positions has been announced by American Steel & Wire Co., United States Steel subsidiary.

Mr. Graf will serve as director of wire rope sales for the Eastern district of the United States, and Mr. Anderson as director of construction material sales for the same district. They will work with the company's sales office in the following cities in connection with their respective products: New York, Buffalo, Pittsburgh, Baltimore, Philadelphia, and Boston.

George H. Cruttenden has been appointed assistant manager, construction material sales, in the company's New York sales office.

•

Ralph R. Brady has been appointed manager of commercial engineering for the **Westinghouse Lamp Division,** Bloomfield, N. J. Mr. Brady, who succeeds the late D. W. Atwater, joined Westinghouse in 1929. He has held various executive positions in the commercial engineering department, which acts as a liaison between the lamp engineering manufacturing and sales departments.

•

Buchanan Electrical Products Corp., Elizabeth, N. J. has appointed Jack E. Olson, 2017 "S" Street, N.W., Washington, D. C. as district manager. He will cover the District of Columbia and the states of Maryland and Virginia. Elton L. Dye, 167 Ritzland Rd., Pittsburgh, Pa. has also been named district

manager. He will cover the western half of the state of Pennsylvania and the entire state of West Virginia.

•

Rome Cable Corporation of Rome, N. Y., has acquired an interest in the Andersen-Carlson Manufacturing Co., Torrence, Calif. Frederick R. Weaver, for many years associated with the Rome Cable Corp., and now residing in South Laguna, California, was elected to the Andersen-Carlson board of directors.

•

George L. Wanamaker, since 1926 assistant to the president of the **National Electric Products Corporation,** Pittsburgh, has been elected by the board of directors to be a vice president of the corporation.

•

The new plants for manufacturing fluorescent lighting equipment are now in operation by the **Miller Company** of Meriden, Conn., in the Mid-West. A fabricating and finishing plant in Utica, Ohio, located north of Columbus, an assembly and shipping plant in Cambridge, Ohio.

•

The Standard Transformer Company of Warren, Ohio, announces the appointment of W. J. O'Brien, 1611 Exchange Building, Memphis, Tenn., as its representative for the state of Tennessee.

•

L. M. Skelton, for many years associated with **Kester Solder Company** of Chicago, as industrial solder engineer, is now representing Kester's technical service department in the field on a specialized basis.

•

Robert L. Hanson has been appointed district manager of the Pittsburgh, Pa. office of **Allen-Bradley Company.**

•

Clay C. Rittenhouse has been appointed representative for the Los Angeles territory for **Curtis Lighting, Inc.,** Chicago.

•

Howard A. Turner has been appointed manager of the Merchandised Products Division of the **Herman Nelson Corporation,** Moline, Ill.

•

Acme Electric Corporation, Cuba, N. Y. has named Charles L. Feigel as export manager.

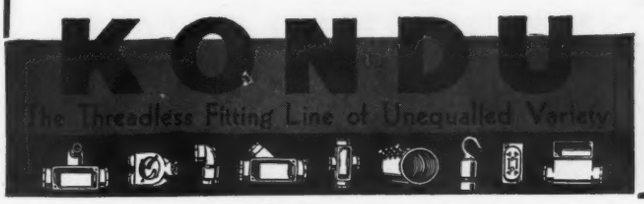
DID YOU KNOW
that you can get
Conduit Fittings
like this?

ALUMINUM ALLOY—2/3 less weight
With no sacrifice of strength, Kondu fittings make a big cut in the weight of conduit lines or portable equipment.

Practically CORROSION PROOF
Many times more resistant to corrosion than other materials previously used for conduit fittings.

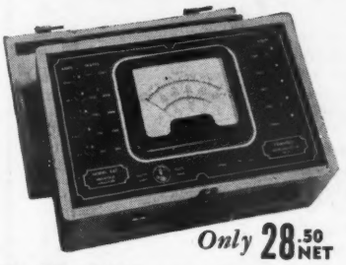
Your choice of THREADED or THREADLESS
Threaded Kondu fittings have covers and other accessories interchangeable with the Threadless line. USE THE RIGHT FITTING every time—there's a Kondu that's exactly suited.

KONDU CORPORATION, Erie, Penna.



KONDU MFG. CO. LTD., Preston, Ontario

The New Model 247 INDUSTRIAL ANALYZER



Only **28.50 NET**

The Model 247 comes housed complete in a beautiful hand-rubbed Oak Cabinet with removable hinged cover.

A special designed, rugged heavy duty current transformer is used for the current ranges.

VOLTS • AMPERES
RESISTANCE • WATTS*

- **Completely portable — No external source of current required.**
- **Individual binding posts for each range reduces to absolute minimum the possibility of damaging meter.**
- **Uses 4½" square rugged meter with large easy-to-read type.**
- **All calibrations printed directly on meter.**

SPECIFICATIONS

A.C. Voltage Ranges—
0 to 150/300/750 volts.

A.C. Current Ranges—
0 to 3/7.5/15/30 amperes.

Resistance—
0 to 20,000 ohms.

Watts*—
0 to 300/750/1500/3000 watts—115v. line
0 to 600/1500/3000/6000 watts—230v. line
*** Watts computed on the basis of Unity Power Factor.**

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Dept. "C-7,"
2937 West 36th St.,
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Send for Bulletin 148

Triangle Instruments Co.
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Please send.....Model 247 Industrial Analyzer.
☐ Full payment $.....enclosed.
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National offers more than insulation and service. *National knows how.* Through actual experience, the National Insulation Engineer knows how his material is manufactured—what it is designed to do—how it performs under the most difficult applications and how to use the insulation most efficiently in your plant.

National Insulation Engineers can offer production hints which often save time and money and make for better employee efficiency.

Use National Service. A complete source of electrical insulation materials. Delivery from large stocks.

You are protected by National's experience and National's extremely particular Inspection Department.

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COLUMBUS 16, OHIO, U. S. A.
ELECTRICAL ENGINEERS MAKERS OF ELECTRICAL COILS AND INSULATION
REDESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

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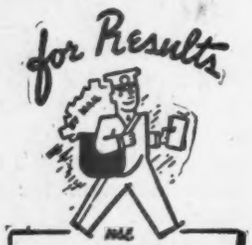

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A machine that reduces labor costs on any contract, whether it be large or small. All piping, conduits, channels, "T's" or angle iron quickly cut to lengths, either in the shop or on the job. High speed, automatic cutting—small investment—simple to operate. Easily mounted on casters for portability—plugs in anywhere. Skilled labor is high priced and scarce. Save it.

Write at once for complete details to

The KALAMAZOO *Metal Cutting* BAND SAW

Used by scores of progressive Contractors

MACHINE TOOL DIVISION
KALAMAZOO TANK AND SILO COMPANY
Harrison and E. Willard Sts. KALAMAZOO 16, MICHIGAN

EQUIPMENT NEWS

[FROM PAGE 211]

Ceiling Sections

New modular "Allouver" ceiling sections are available in 18 in. by 48 in. sections made up of either 3 in. or 1½ in. cubes. They are made of aluminum and can be sprayed and baked to match any specific color. They are not suspended on "T" bars but by a hinged-catch mechanism on telescoping rods. Thus, a single section can be unhinged or removed without disturbing the remaining sections. When the "Allouver" ceiling is in place, it presents an unbroken front without a grid pattern, giving the illusion of natural daylight lighting. General Lighting Company, Inc., 32 Union Square, New York, N. Y.

Transformer

Constant voltage ballast transformer, type CVM-1, is designed to protect and stabilize the operation of G-E Type UA-4 mercury vapor lamp. Operation of lamp is stable and free from effects of improper or widely varying line voltage. Lamp life is increased by preventing over voltage operation. Lamp outages resulting from momentary voltage drops are eliminated. There can be no damage to lamp from improper selection of primary taps. Lamp operates on 115 volt lighting circuits. Sola Electric Co., 2525 Clybourn Ave., Chicago 14, Ill.

Alternators

Katolight alternators are now available in 187 kva. size, 1800 rpm. with directly connected exciter. Ten to twelve lead wires are brought out into a steel cabinet located on the side of the generator. The voltage regulator, voltmeter, and ammeter are mounted on top of cabinet isolated by rubber to keep vibration away from regulator and meters. Exciter armature is on independent shaft. Frames are of welded steel construction. Endbells are of ribbed cast iron. Fan made of aluminum blades riveted to steel disc center provides flow of cooling air through both stator and rotor. Alternator rotors are banded to protect against damage from over speed. Kato Engineering Company, Mankato, Minn.

Emergency Lighting System

This portable emergency lighting system, called Minuteman, supplies light from its own power when usual source of current fails. Each lamp head delivers about 100 watts of light and is capable of illuminating approximately 10,000 square feet for about five hours. Lamp heads are adjustable to any position and may be removed from unit for installation on walls, stairways, etc. When normal current is resumed, lights automatically go out and

a built-in charger restores power to battery for next emergency. It plugs into any convenient outlet in the lighting circuit. Unit carries approval of Underwriter's Laboratories. Electric Cord Company, 30 Church Street, New York 7.

New Equipment Briefs

Mitchell Manufacturing Company, Chicago, Ill., has announced a commercial **fluorescent striplighting**, known as "Super-Strip", for individual or continuous row mounting. . . . A 36-inch slimline **germicidal** lamp capable of operating at four different germ-killing intensities has been developed by General Electric Co., Nela Park, Cleveland. . . . A new general purpose **level control** for the chemical processing industry has been announced by Photoswitch Incorporated, Cambridge, Mass.

Micro Switch of Freeport, Ill. has announced a new interlock door **switch** designed for use on high frequency radio, induction heating equipment, and electronic controls. . . . A new 4-wheel **hand truck,** called Rol-Away, is for handling pipe tubing, bar stocks, rods, molding, lumber and other long narrow pieces. It is manufactured by Beall Pipe and Tank Company, Portland 3, Ore. . . . A **midget hydraulic unit** suitable for automatic or remote control of hydraulic cylinders, or as a substitute for compressed air has been announced by John Dusenbery Company, Montclair, N. J.

A new non-creeping close differential **current relay** has been added to the line of controls manufactured by the Automatic Switch Company, Orange, N. J. . . . A new kit of carbide tipped, super-grip, hex drive **masonry drills** in six sizes. 3/16, 1/4, 5/16, 3/8, 1/2 and 5/8 inches is available from Super Tool Company, Detroit, Mich. . . . Ingersoll-Rand Company, Phillipsburg, N. J. has announced a new air-powered **generator,** known as Airlite. It uses compressed air to provide light for construction, shaft sinking, repair and public utility jobs.

The Tel-E-Lect **pole digger** attaches to a regular line truck that is equipped with rear or front derrick. It is made by the Minnetonka Mfg. Co., Minneapolis, Minn. . . . Globe Lighting Products, Inc. of New York has brought out a new residential **fluorescent unit** featuring "wing-tip" contour. Each unit is equipped with two lights, 20 or 40 wattts. . . . Mathias Klein & Sons, Chicago, has developed a set of matched, right and left **climbers,** called the "Pole Master".

Lock-line **pliers** are designed to act as wire pullers, pipe pliers, lineman's pliers, wire cutters, small bolt cutter and a locking device. They are manufactured by Ross Manufacturing Co., San Francisco, Calif. . . . An improved radial ceiling **ventilating fan** has been announced by Shepler Manufacturing Co., Pittsburgh, Pa. . . . Adjustable

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PROMPT SHIPMENT FROM LARGE STOCK

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READING ELECTRIC COMPANY, INC.

Parts Distributors for the Manufacturer

102 Park Row ***Beekman 3-7800*** **New York 8, N. Y.**

Take this "Eliptor" Flood, for instance. I can stand right here and make every adjustment—I can see the degree markings and note them down so the flood can always be set the same way. And, the wiring too is simple! Smart design—what you'll always find in REVERE units.

Revere 5000 watt Flood for stadium lighting. We make types to suit every lighting need from 100 watts up.

Revere No. 4200—ingeniously designed—has double parabolic reflector offering high lighting efficiencies. Ideal for Baseball—Softball—Football installations.

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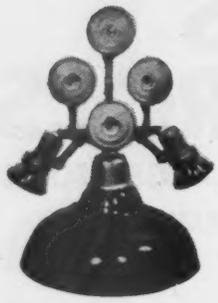
WRITE FOR SAMPLES and the Ilsco 54-page illustrated catalog.

ILSCO COPPER TUBE & PRODUCTS, Inc. CINCINNATI, OHIO

Floodlighting by

Rab ELECTRIC MFG. CO.



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Rabolite

THE MOST VERSATILE OUTDOOR FLOODLIGHTING LINE

FOR MULTIPLE UNIT OR SINGLE UNIT WALL MOUNTING

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KNOWN FOR EASE OF WIRING, DEPENDABILITY OF PERFORMANCE

FOR SETTING INTO GROUND—

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SOLD ONLY THRU RECOGNIZED WHOLESALERS

WRITE FOR CATALOG TODAY

pole climbers, with an extension shank or leg iron that can be set any desired length between 15 and 18½ inches has been introduced by Buckingham Manufacturing Co., Inc., Binghamton, N. Y.

The Instrument Division of Thomas A. Edison, Inc., West Orange, N. J. has developed a **temperature controller,** using a single electronic tube with an electrical resistance type bulb for thermal pick-up. . . . The Weller Mfg. Co., Easton, Pa. has announced two new **soldering gun** models designed for use on 110 or 200 volts at 50 or 60 cycles. . . . A new corrosion-proof **plastic pipe** has been developed by United States Rubber Company for use in chemical manufacturing, mining.

Lisbon Hoist and Crane Company, Lisbon, Ohio, has introduced new three and five ton capacity **hoists** to the "Bob-Cat" line. . . . A new model ¼ inch high power portable **electric drill** for industrial and home workshop use has been announced by Portable Electric Tools, Inc., Chicago, Ill. . . . A new jiffy no-kink **fish tape** for aluminum and steel conduit has been announced by Clyde W. Lint Co., Chicago, Ill.

A new all purpose line of carbide tipped **masonry drills,** including round-shank drills for shallow holes and fluted shank drills for deep holes, has been announced by Carboloy Company, Inc., Detroit, Mich. . . . A new No-Rol cage for portable **lamp guards** made by the McGill Manufacturing Company, Inc., Valparaiso Ind.

WHERE TO BUY

Equipment, Materials, Supplies and Services for Electrical Construction — Maintenance—Repairs

How to drill concrete

for expansion bolts, conduit, etc.

You can drill holes through concrete walls, floors, ceilings, 12 to 15 times faster than by hand. Use the Wodack Do-all Electric Hammer. Typical example: drills a ⅜" hole 1" deep through average concrete in less than 15 seconds! Saves time and money. You also use Wodack Do-all for chipping concrete, drilling wood, metal, etc. Investigate.

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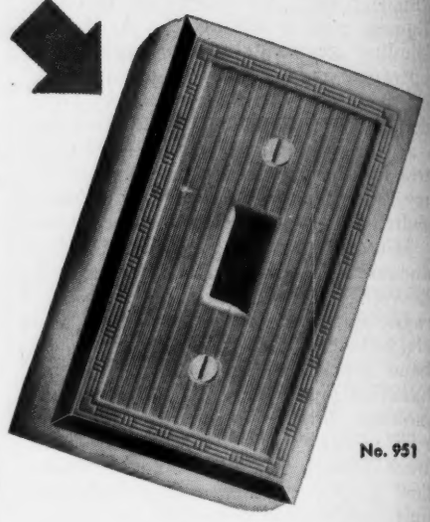
Wodack Electric Tool Corporation
4627 W. Huron St. Chicago 44, Ill.

When you're in need of some product or service to speed and improve operation, or save money, you may find it here—in the Where To Buy Section. It pays to check this page . . . *each issue.*

Note the design



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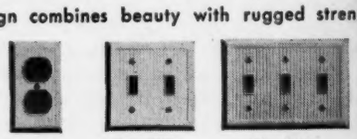
Extra heavy Bakelite FLUSH PLATES

FOR TOP QUALITY JOBS

Pressed heavy Bakelite in this widely popular design combines beauty with rugged strength.



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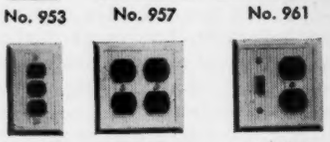

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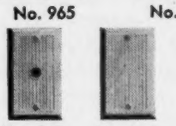

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Each plate packaged in an individual envelope complete with METAL screws.

ORDERS SHIPPED IMMEDIATELY . . . WRITE FOR SAMPLES AND DETAILED INFORMATION

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